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We sincerely wish the happy and healthy days to all my colleagues and their families. We are happy to accomplish the third issue of 2017.

There are 5 clinical research articles in this issue. The first article is analysis of the spinal canal diameters. In the second article, in the patients with transitional vertebral deformity, iliolumbar ligaments are analyzed. In the third study, the result of the anterior discectomies in the 338 patients are presented. In the fourth study is from Adana which was analyzed F18-FDG PET-CT in diagnosing, treating and monitoring of spinal infections Fifth study is about clinical outcome of the ultrasound guided epidural injection.

In this issue, 2 case report and a case series are presented. In the case series is about spinal surgery complicated with some congenital and childhood neural diseases

Percutaneous sacroplasty for the treatment of sacral pedicle screw loosening in an osteoporotic patient was reported. Second one is about the OPL calcification.

In this issue, a review article were included. In this review article, congenital chest wall deformities associated spinal deformities were presented.

In this issue, in the "Frontiers of the Spinal Surgery" section, the sections about spinal fractures in the book of Razi are reported.

We wish healthy, successful and peaceful days to Turkish Spinal Surgery family and we present our deepest respects.

Prof. Dr. İ. Teoman BENLİ

JTSS Editor

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EDITORIAL

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CASE REPORT

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FRONTIERS OF SPINAL SURGERY

Volume: 28, Issue: 3, July 2017 pp: 151-154 ORIGINAL ARTICLE

LUMBAR SPINAL CANAL DIAMETERS AND AREA MEASUREMENTS IN HEALTHY INDIVIDUALS

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SUMMARY

Objective: We aimed to the lumbar spinal canal lengths and area measurements were measured in normal healthy individuals between 20 and 50 years of age in the Turkish population by Magnetic Resonance Imaging (MRI).

Material and Methods: Three measurements were analyzed in axial MRI of 50 (30 male, 20 female) healthy individuals in 20-50 age groups (mean age:33,69±12). In T2-weighted fast spin-echo (FSE) axial MR images, measurements were obtained at L3-4, L4-5, L5-S1 levels. Measured lumbar spinal canal anterior-posterior diameter (DSAPD) mm and spinal canal transverse diameter (DSTD), mm and spinal canal cross-sectional area (DSCSA), mm^2 measurements in healthy individuals by axial MRI (figure1,2,3). SIGNA Explorer GE 1,5 T MR device used. The patients were placed in the supine position with a cushion under both knees. T2-weighted FSE axial and sagittal images were obtained (TR/TE, 3213.48/100.00 ms for axial scan and 3207.27/100.00 ms for sagittal scan; slice thickness, 4 mm; slice gap, 0.4 mm; field of view, 16 cm for axial scan and 32 cm for sagittal scan; matrix, 256 × 216 of axial scan and 512 × 252 for sagittal scan; flip angle, 90°; ETL, 18; and excitations, 3). On T2-weighted FSE axial images, spinal canal diameter and area measurements were performed.

Results: Lumbar spinal canal measurements; Lumbar DSAPD L3-4 (24,46± 2,12) mm, L4-5 (22,86± 2,07) mm, L5-S1 (20,36± 2,13) mm, DSTD L3-4 (27,16± 2,10) mm, L4-5 (27,06± 2,03) mm, L5-S1 (26,46± 2,47) mm, lumbar DSCSA L3-4 (27,20± 2,14) mm^2, L4-5 (25,46± 2,07) mm^2, L5-S1 (23,46± 2,27) mm^2 were measured in healthy individuals.

Conclusion: In evaluating lumbar spinal stenosis, it is necessary to know the lumbar spinal canal measurements in normal individuals. MRI is an important examination in evaluating lumbar spinal canal measurements.

Keywords: Lumbar Spinal Canal, Lumbar Spinal canal, Magnetic Resonance Imaging.

Level of evidence: Retrospective Clinical Study, Level III

INTRODUCTION

We aimed to the lumbar spinal canal lengths and area measurements were measured in normal healthy individuals between 20 and 50 years of age in the Turkish population by MRI. MRI is the most diagnostic method for spinal pathologies. Degenerative changes in facet joints can be in the form of facet hypertrophy, osteophytes spur development, cartilage narrowing, joint effusion, and capsular hypertrophy, all of which can be assessed in detail by MRI [(4).] Axial and sagittal MRIs typically show narrowed spinal canals.

In lumbar spinal stenosis, T1-weighted images are useful for evaluating the width and contours of the foramen and conus medullaris. T2-weighted images provide an accurate assessment of spinal canal diameters. The decrease in epidural fat tissue due to the hypertrophic bone, T1 and T2 weighted image with low density, hypertrophic ligament flavum, T1 and T2 weighted images and moderate thickening and prolonged compression appear as a dark color from high to low on the T1 signal. The fat signal around the nerve root (seen best in T1-weighted images) appears to be reduced in axial and sagittal images [(1,2).] MR examination has several advantages over CT. The patient does not receive ionizing radiation and the procedure is non-invasive. Also, the

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patient does not need to be in the hospital. As with myelography, all lumbar vertebrae can be visualized. Soft tissue evaluation of conus, cauda equina, and nerve roots is better than CT. Ligamentum flavum, disc herniation and intraspinal synovial cysts are more common in imaging than other methods. MR is superior to CT and myelography in predicting the loss of epidural fat tissue [3-5].

MRI examination also has some disadvantages. In the case of lumbar spinal stenosis, cortical bone and osteophytes are less visible. MRI examinations can not be performed on those who have non-titanium metal devices in the spine, eyes and cranium, pacemakers and claustrophobia. MRI is also a more expensive test than CT [5-12,14].

To assess spinal stenosis, spinal canal diameters need to be known in normal healthy individuals. Therefore, we have measured these lumbar spinal canal measurements in a limited number of healthy individuals.

MATERIALS AND METHODS

Three measurements were analyzed in axial MRI of 50 (30 male, 20 female) healthy individuals in 20-50 age groups (mean age:33,69±12). In T2-weighted fast spin-echo (FSE) axial MR images, measurements were obtained at L3-4, L4-5, L5-S1 levels. Measured lumbar spinal canal anterior-posterior diameter (DSAPD) mm and spinal canal transverse diameter (DSTD), mm and spinal canal cross-sectional area (DSCSA), mm^2 measurements in healthy individuals by axial MRI (figure1,2,3). SIGNA Explorer GE 1,5 T MR device used. The patients were placed in the supine position with a cushion under both knees. T2-weighted FSE axial and sagittal images were obtained (TR/TE, 3213.48/100.00 ms for axial scan and 3207.27/100.00 ms for sagittal scan; slice thickness, 4 mm; slice gap, 0.4 mm; field of view, 16 cm for axial scan and 32 cm for sagittal scan; matrix, 256 × 216 of axial scan and 512 × 252 for sagittal scan; flip angle, 90°; ETL, 18; and excitations, 3). On T2-weighted FSE axial images, spinal canal diameter and area measurements were performed.

Image Analysis

Three radiologists (readers 1,2,3) participated in all three-step evaluations in this study. Before the review of the lumbar MRIs in the pre-step evaluation, three radiologists discussed the measurements of the lumbar spinal canal and established a consensus measurements that they would use on T2-weighted axial images. All evaluations were completed, one radiologist (reader 1) repeated the last second-step evaluation to allow calculation of intra-reader agreement and also to measure. DSCSA, DSAPD, and DSTD on T2-weighted axial images and on T2-weighted mid-sagittal images at each disc level of the lumbar spine working manually at a Workstation.

Ethics Committee approved and written consent form was taken from all the volunteers. Those with spondylodiscitis, who underwent disc surgery, and those with inflammatory diseases such as ankylosing spondylitis were excluded from the study.

Statistical Package for Social Sciences (SPSS) v23.0 (IBM co. Chicago IL) was used for statistical analyses. ANOVA test was used.

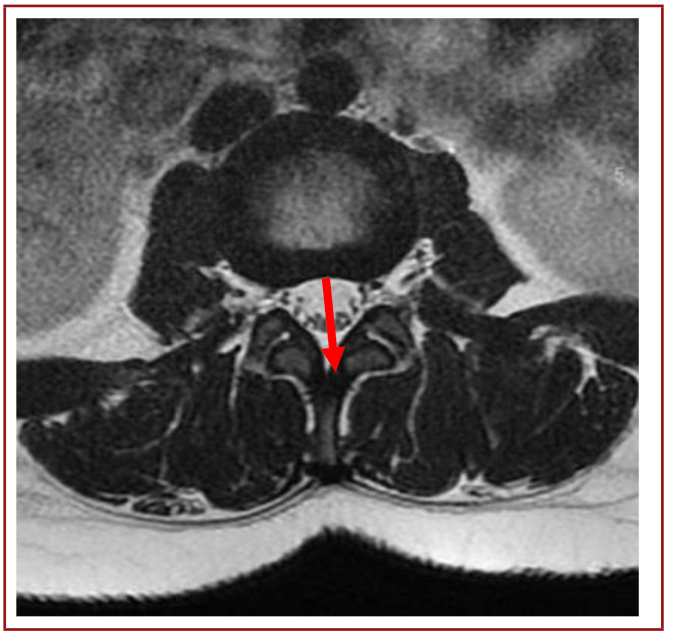

Figure-1. Lumbar spinal canal anterior-posterior diameter measurements.

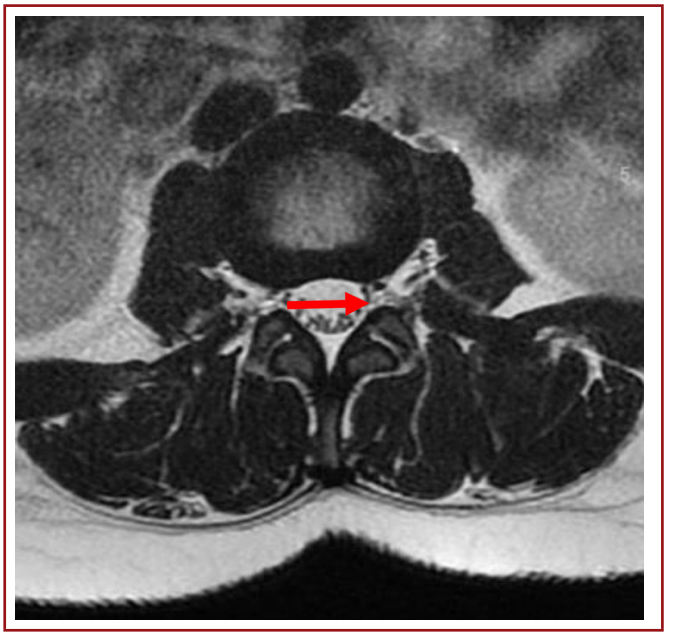

Figure-2. Lumbar spinal canal transverse diameter measurements.

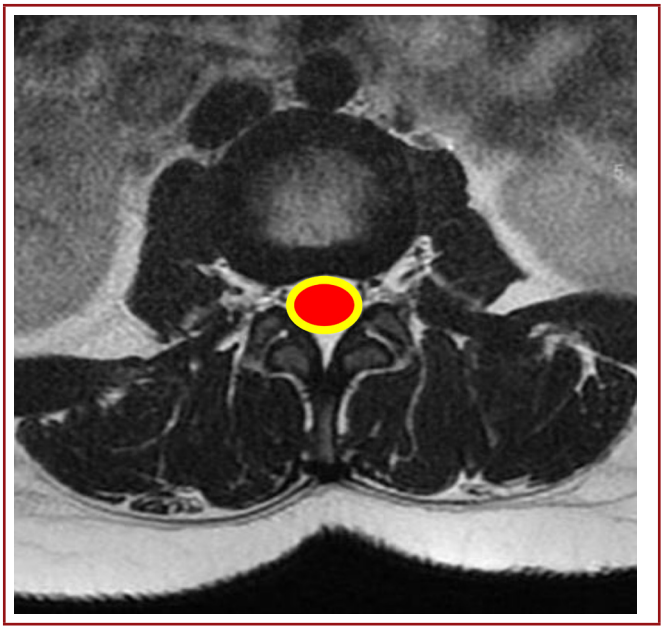

Figure-3. Lumbar spinal canal cross-sectional area measurements.

RESULTS

Lumbar spinal canal measurements; Lumbar DSAPD L3-4 (24,46± 2,12) mm, L4-5 (22,86± 2,07) mm, L5-S1 (20,36± 2,13) mm, DSTD L3-4 (27,16± 2,10) mm, L4-5 (27,06± 2,03) mm, L5-S1 (26,46± 2,47) mm, lumbar DSCSA L3-4 (27,20± 2,14) mm^2, L4-5 (25,46± 2,07) mm^2, L5-S1 (23,46± 2,27) mm^2 were measured in healthy individuals (Table-1,2).

Table-1. Lumbar spinal canal anterior-posterior diameter and transverse diameter measurements.

Lumbar Levels	Spinal canal antero-posterior Diameter Mean± SD	Spinal canal transverse Diameter Mean± SD
L3-4	24,46± 2,12	27,16± 2,10
L4-5	22,86± 2,07	27,06± 2,03
L5-S1	20,36± 2,13	26,46± 2,47

Table-2. Lumbar spinal canal cross-sectional area measurements.

Lumbar Levels	Spinal canal cross-sectional Area Mean± SD
L3-4	27,20± 2,14
L4-5	25,46± 2,07
L5-S1	23,46± 2,27

DISCUSSION

It is usually due to degenerative changes of the vertebral column in the elderly, resulting in lumbar spinal stenosis. Nowadays, the increase in the average age of the population increases the importance of degenerative lumbar spinal stenosis. Patients with neurogenic claudication or sciatica complaints are restricted in their functional activities and become dependent on the bed. Lumbar spinal stenosis typically occurs as a result of complex degenerative processes that produce pressure in neural elements. Spinal stenosis, central cord stenosis, lateral recess stenosis, degenerative spondylolisthesis or confusion due to all three. In addition to these findings, disc herniation may be accompanied by pathology. Degenerative stenosis and lumbar spondylosis are thought to occur due to recurrent axial loading and rotational constraints, facet hypertrophy, ligamentum flavum thickening, and osteophyte formation. Other causes of spinal stenosis include postoperative, post-traumatic, neoplastic, infectious, bone disease-related (as in Paget's disease), congenital stenosis (achondroplastic form).

On the basis of the results of previous studies, a >15 mm^2 change in the DCSA induced by axial loading was defined as a significant change,[15-17] worsening the severity of the clinical symptoms[9]. If the anterior posterior diameter of the lumbar canal is less than 10 mm, it is considered as an absolute stenosis. If this diameter is less than 13 mm, it is regarded as relative stenosis [3,13].

The results we have found in our study are consistent with previous literature studies. Until now, there is no study of normal spinal canal measurements in the Turkish population.

Among the limitations of this study, it is not possible to standardize on the gender, age, weight, and height of the individuals taken into the study. This study is limited to only 50 people and it is a preliminary study. In future studies, the number of working groups should be increased. In order to standardize lumbar spinal canal measurements in Turkish society, there is a need for further studies.

In evaluating lumbar spinal stenosis, it is necessary to know the lumbar spinal canal measurements in normal individuals. MRI is an important examination in evaluating lumbar spinal canal measurements.

REFERENCES

1. Amundsen T, Weber H, Lilleas F, Nordal HJ, Magnaes B, Abdelnoor M, **Lilleâs F**. Lumbar spinal stenosis clinical and radiologic features. *Spine* 1995; 10: 1178-1186.
2. Binder DK, Schmidt MH, Weinstein PR. Lumbar spinal stenosis. *Semin Neurol* 2002; 2: 157-165.

3. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *J Bone Joint Surg* 1990;72-A: 403-408.

4. Epstein NE, Epstein JE. Lumbar decompression for spinal stenosis. In: Frymoyer JW (Ed.), *The Adult Spine: Principles and Practice*. Lippincott-Raven, Philadelphia 1997; pp: 2055-2088.

5. Haba K, Ikeda M,Soma M, Yamashima T. Bilateral decompression of multilevel lumbar spinal stenosis through a unilateral approach. *J Clin Neurosci* 2005; (2): 169-171.

6. Herno A, Airaksinen O, Sari T. Long-term result of surgical treatment of lumbar spinal stenosis. *Spine* 1993; 18(11): 1471-1474.

7. Kanno H, Ozawa H, Koizumi Y, **Koizumi Y,** Morozumi N, Itoi E, Ishii **Y.** Dynamic change of spinal canal cross-sectional area in axial loaded magnetic resonance imaging correlates with the severity of clinical symptoms in patients with lumbar spinal canal stenosis. *Spine* 2012; 37: 207–213.

8. Önel D, Sarı H, Dönmez Ç. Lumbar spinal stenosis: Clinical/radyologic therapeutic evaluation in 145 patients. *Spine* 1993; 18(2): 291-298.

9. Pappas CTE, Sonntag VKH. Degeneratif disorders of the spine: lumbar stenosis. In: Menezes AH, Sonntag VKH, Benzel EC (Eds.). *Principles of Spinal Surgery*, 1996; 631-644.

10. Porter RW. Spinal stenosis and neurogenic claudication. *Spine* 1996; 21(17): 2046-2052.

11. Rauschning W. Anatomy and patology of the lumbar spine. In: Frymoyer JW (Ed.), *The Adult Spine*. Lippincott-Raven, Philadelphia 1997; pp: 1687-1703.

12. Roland M, Fairbank J. The Roland-Morris disability questionnaire and the Oswestry disability questionnaire. *Spine* 2000; 25(24): 3115-3124.

13. Ullrich CG, Binet EF, Sanecki MG, Kieffer SA. Quantitative assessment of the lumbar spinal canal by computed tomography. *Radiology* 1980; 134: 137-143.

14. White AA, Panjabi MM. *Clinical Biomechanics of the Spine*. 2nd ed., Lippincott, Philadelphia 1990.

15. Willén J, Danielson B, Gaulitz A, Niklason T, Schönström N, Hansson T. Dynamic effects on the lumbar spinal canal: axially loaded CT-myelography and MRI in patients with sciatica and/or neurogenic claudication. *Spine* 1997; 22: 2968–2976.

16. Willén J, Danielson B. The diagnostic effect from axial loading of the lumbar spine during computed tomography and magnetic resonance imaging in patients with degenerative disorders. *Spine* 2001; 26: 2607–2614.

17. Willén J, Wessberg PJ, Danielsson B. Surgical results in hidden lumbar spinal stenosis detected by axial loaded computed tomography and magnetic resonance imaging: an outcome study. *Spine* 2008; 33: E109–115.

Volume: 28, Issue: 3, July 2017 pp: 155-158 ORIGINAL ARTICLE

ANALYSIS OF ILIOLUMBAR LIGAMENT ON LUMBOSACRAL TRANSITIONAL ANOMALIES

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SUMMARY

Objective: Our aim is to understand if there is a relationship about the numbering of LSTV with iliolumbar ligament or not.

Materials and Method: We inspected 350 lumbar MRI. Any pathologies or traumatic injuries with lumbosacral segment were excluded from the study. We found 58 patient with LSTV and 210 patient as control group without any pathology or segmental anomalies. LSTV patients were classified according to the Castellvi classification.

Results: The ILL originated in 100 % from the L5 vertebra in the control group. The ratio in the Castellvi type I group was 85.7 %. In the type II and higher group, the ILL originated only from L5 is 29.5 %.

Conclusion: We observed that ILL was always present and its origin always involved the last lumbar vertebra but the level of the origin of the ILL is unreliable for identification of the L5 vertebra in the setting of a LSTV type II or higher.

Key words: Lumbosacral transitional vertebra, Iliolumbar ligament, Lumbalization, Sacralization

Level of Evidence: Retrospective clinical study, Level III

INTRODUCTION

If the last lumbar vertebra shows elongation of its transverse process, with varying degrees of fusion to the first sacral segment, it is defined as lumbosacral transitional vertebrae (LSTV) [10]. Bertolotti first described the assimilation of the fifth lumbar vertebra into the sacrum and its association with lower back pain in 1917 [1]. LSTV are common in the general population, with a reported prevalence of 4–21 % [7]. Lumbar spine magnetic resonance imaging (MRI) can sensitively identify LSTV on based on abnormal morphology of the lumbosacral junction but there is no standard method is established for their numbering [6].

During the preparation of lumbosacral spinal surgeries, LSTV must be recognized. Otherwise the level of surgery, incision and trajectory could be incorrect. Many literature reported that the origin of the iliolumbar ligament (ILL) has been suggested as a reliable identifier of the L5 vertebra as it originates from L5 in 97-100 % of patients without segmentation anomalies [2,4,7,11].

We made an observational analyze of ILL on LSTV to understand if there is a relationship with the numbering of lumbosacral vertebras with LSTV or not.

MATERIALS AND METHODS

We inspected 350 lumbar MRI. Any pathologies or traumatic injuries with lumbosacral segment were excluded from the study. We found 58 patient with LSTV and 210 patient as control group without any pathology or segmental anomalies. LSTV patients were classified according to the Castellvi classification [3] (Table-1).

RESULTS

The ILL originated in 100 % from the L5 vertebra in the control group. The ratio in the Castellvi type I group was 85,7 %. In the other group, the ILL originated only from L5 is 29,5 %. The other results are listed on Table-2.

Finally we observed that ILL was always present and its origin always involved the last lumbar vertebra but the level of the origin of the ILL is unreliable for identification of the L5 vertebra in the setting of a LSTV type II or higher.

Table-1. Castellvi classification of LSTV

TYPE	DESCRIPTION
Type I	Dysplastic transverse process (unilateral: Ia; bilateral: Ib)
Type II	Incomplete lumbarization /sacralization showing enlarged transverse processes with unilateral (IIa) or bilateral (IIb) pseudarthrosis with the adjacent sacral ala.
Type III	Complete lumbarization/sacralization showing enlarged transverse processes, with unilateral (IIIa) or bilateral (IIIb) fusion with the adjacent sacral ala
Type IV	Mixed (eg, type IIa on one side and type IIIa on the other)

Table-2. Results of our observation according to Castellvi classification

	Control	LSTV Type I	LSTV Type II and more
ILL originating only from L5	210 (100%)	12 (85.7%)	13 (29.5%)
ILL with multiple origins	0 (0%)	2 (14.3%)	28 (63.6%)
ILL with no origins from L5	0 (0%)	0 (0%)	3 (6.9%)

DISCUSSION

LSTV is best identified with a true 30˚ angled anteroposterior X-ray of the lumbosacral junction together with an anteroposterior view including the thoracolumbar junction to enable assessment of the vertebral level [6]. If an LSTV is suspected on MRI, the decision of whether it represents a sacralized L5 or lumbarized S1 must be made [13]. The true nature of the lower vertebral segmentation can be established only on conventional radiographs that include the thoracolumbar junction so that hypoplastic true ribs may be differentiated from large transverse processes, thus allowing correct identification of the L1 vertebral body [8].

If inaccurate results occur frequently when the location is only determined from a lumbar radiograph or when MRI is used alone, surgery could be performed on areas other than those intended because the localization of the condition could be potentially flawed [5,9]. The reason for such results in most cases is due to the presence of an accompanying TV. For a TV of the lumbosacral area, an anatomically S1 vertebra that appears morphologically as an L5 vertebra is referred to as lumbarization also an L5 vertebra that appears as an S1 vertebra is referred to as sacralization [3,5,7,12].

We observed that an ILL was always present and its origin always involved the last lumbar vertebra but the level of the origin of the ILL is unreliable for identification of the L5 vertebra in the setting of a LSTV type II or higher. When we search the literature we found that Farshad-Farshad-Amacker et al., Carrino et al., Hughes et al. and Lee et al. have made similar studies and our results are supporting them [2,4,6-7].

REFERENCES

1. Bertolotti M. Contributo alla conoscenza dei vizi di differenzazione regionale del rachide con speciale riguardo all assimilazione sacrale della v. lombare. *Radiol Med* 1917; 4: 113–144.
2. Carrino JA, Campbell PD, Lin DC, Morrison WB, Schweitzer ME, Flanders AE, et al. Effect of spinal segment variants on numbering vertebral levels at lumbar MR imaging. *Radiology* 2011; 259: 196-202.
3. Castellvi AE, Goldstein LA, Chan DP. Lumbosacral transitional vertebrae and their relationship with lumbar extradural defects. *Spine* 1984; 9: 493-495.
4. Farshad-Amacker NA, Lurie B, Herzog RJ, Farshad M. Is the iliolumbar ligament a reliable identifier of the L5 vertebra in lumbosacral transitional anomalies? *Eur Radiol*. 2014; 24(10): 2623-2630.
5. Hahn PY, Strobel JJ, Hahn FJ. Verification of lumbosacral segments on MR images: identification of transitional vertebrae. *Radiology* 1992; 182(2): 580–581 .

6. Hughes RJ, Saifuddin A. Numbering of lumbosacral transitional vertebrae on MRI: role of the iliolumbar ligaments. *AJR Am J Roentgenol* 2006; 187: W59-65.
7. Lee CH, Park CM, Kim KA, Hong SJ, Seol HY, Kim BH. Identification and prediction of transitional vertebrae on imaging studies: anatomical significance of paraspinal structures. *Clin Anat* 2007; 20: 905-914.
8. Liu K-C, Xiang G-Z, Chen G-H, Zhou Y, Cao X-Q, Xia J-D. [CT axial imaging of the iliolumbar ligament and its significance on locating lumbosacral vertebral segments]. *Zhongguo Gu Shang* 2010; 23: 854-858.
9. Malanga GA, Cooke PM. Segmental anomaly leading to wrong level disc surgery in cauda equina syndrome. *Pain Physician* 2004; 7(1): 107–110 .
10. O'Driscoll CM, Irwin A, Saifuddin A. Variations in morphology of the lumbosacral junction on sagittal MRI: correlation with plain radiography. *Skeletal Radiol* 1996; 25: 225-230.
11. Rucco V, Basadonna PT, Gasparini D. Anatomy of the iliolumbar ligament: a review of its anatomy and a magnetic resonance study. *Am J Phys Med Rehabil* 1996; 75: 451-455.
12. Tini PG, Wieser C, Zinn WM. The transitional vertebra of the lumbosacral spine: its radiological classification, incidence, prevalence, and clinical significance. *Rheumatol Rehabil* 1977; 16(3): 180–185 .
13. Wigh RE. The thoracolumbar and lumbosacral transitional junctions. *Spine* 1980; 5: 215-222.

Volume: 28, Issue: 3, July 2017 pp: 159-162 ORIGINAL ARTICLE

ANALYSIS OF ANTERIOR CERVICAL DISCECTOMIES: EVALUATION OF 338 CASES

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SUMMARY

Objective: The aim of our study is to analyse the cervical discectomy operations performed in our clinic in the last 3 years.

Materials and Method: 338 patients underwent anterior cervical discectomy+fusion or total disc replacement at Adana Numune Training and Research Hospital Neurosurgery Clinic between April 2013 and April 2016 were inspected retrospectively. We evaluated patients' age, gender, level of discopathy, side of the disc herniation, type of surgery, preoperative and postoperative Visual Analog Scale(VAS) scores.

Results: Data from 338 patients were included in the statistical analyses. Mean age of the study population was 46.1 ± 10.3 years, and male/female ratio was 171 / 167. 145 patients(42.9 %) had a localization at C_5-C_6. The symptoms were on the left side of 43,5 % of patients. Total disc replacement implanted on 203 patients (60.1 %) and 135 patients(39.9 %) had been operated with fusion cages with blade. VAS scores decreased significantly during follow-up period. The comparisons of clinical characteristics between males and females were similar. But postoperative 3rd month VAS scores were significantly different between genders, and males had lower VAS scores than females.

Conclusion: Cervical disc disease is a common pathology. Anterior cervical discectomy is a frequently performed procedure in surgical treatment. Anterior cervical discectomy + fusion or total disc replacement can be performed.

Key words: Cervical disc herniation, anterior cervical discectomy, total disc replacement

Level of evidence: Retrospective clinical study, Level III

INTRODUCTION

Anterior cervical discectomy(ACD) is the most commonly used procedure for cervical disc herniation. Many techniques and modalities of fixation are used in ACD. Each one has some advantages and disadvantages against the others.

The first surgical approach to cervical disc disease was performed by Victor Horsley with posterior approach in 1895. Then Smith and Robinson described the anterior cervical discectomy and fusion technique in 1955 [13]. Anterior approach is more preferred in recent years. Autograft bone placement is recommended for the fusion [3,5]. Autograft bone fusion has complications like graft collapse, graft removal and loss of cervical lordosis. Cage implantation has been used frequently in recent years for the fusion. But fusion causes adjacent segment disease (ASD).

Some authors suggest total disc replacement (TDR) to prevent ASD[2]. The incidence of heterotopic ossification in TDR usage is 1,4-15,2 %[19]. Pseudoarthrosis and fusion develop on long-term follow-up. Also the cost is quite high. Treatment options are wide and not clear.

In our retrospective study we try to analyze our 3 years experience of anterior cervical discectomy procedures.

MATERIALS AND METHODS

Three hundred and thirty eight patients whom operated for cervical disc herniation with anterior cervical discectomy procedure between April

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2013 and April 2016 at Adana Numune Training and Research Hospital Neurosurgery Clinic were evaluated for the study. Traumatic and spondylotic patients were not included in the study.

Patient information's were accessed from archive files retrospectively. Radiological data were inspected from the PACS system. In this study we evaluated the level of discopathy, side of the disc herniation, type of surgery, preoperative and postoperative Visual Analog Scale (VAS) scores.

Statistical Analysis

Descriptive data were presented as mean and standard deviations, or median and min-max values for numerical variables, and frequencies and percent for categorical variables. Independent group comparisons were analyzed with Mann-Whitney U test between genders. Changes over time in VAS scores were analyzed with Friedman non-parametric analysis of variance test. A Type I error level of 5% was considered as statistical significance in analyses. SPSS 18 (IBM Inc., Armonk, USA) was used for the statistical assessments.

RESULTS

Data from 338 patients were included in the statistical analyses. Mean age of the study population was 46.1±10.3 years, and male/female ratio was 171/167 (50.6% vs. 49.4%). Patient demographics was presented in Table-1.

The clinical characteristics of the patients were presented in Table-2. Accordingly, 43.5% of the patients had complaints in their shoulders and left arms at admission, 42.9% of the patients had a localization at C_5-C_6, preoperative deficits were present in 29.6% of the patients, 60.1% of patients had cervical disc prosthesis, and 39.9% of cases had blade cages.

The changes in preoperative and postoperative VAS scores were presented in Table-3. Analyses revealed that VAS scores decreased significantly during follow-up period ($p<0.001$).

The comparisons of clinical characteristics between males and females revealed that complaints at admission ($p=0.401$), localization of complaints ($p=0.169$), presence of preoperative deficits ($p=0.537$), and materials used in operations ($p=0.087$) were similar between genders (Table-4).

The preoperative and postoperative 1st day VAS scores were not statistically different between males and females. But, postoperative 3rd month VAS scores were significantly different between genders ($p=0.014$), and males had lower VAS scores than females (Table-5).

Table-1. Patients' demographics

	Mean±SD
Age	46.1±10.3
	n (%)
Gender	
Male	171 (50.6)
Female	167 (49.4)

Table 2. Clinical characteristics of patients

	n (%)
Complaint at admission	
Shoulder & left arm	147 (43.5)
Shoulder & right arm	62 (18.3)
Shoulder	57 (16.9)
Shoulder & both arms	52 (15.4)
Both arms	8 (2.4)
Right arm	6 (1.8)
Left arm	6 (1.8)
Localization	
C_5-C_6	145 (42.9)
C_6-C_7	103 (30.5)
C_5-C_6, C_6-C_7	29 (8.6)
C_4-C_5	25 (7.4)
C_4-C_5, C_5-C_6	15 (4.4)
C_3-C_4	8 (2.4)
C_4-C_5, C_5-C_6, C_6-C_7	5 (1.5)
C_4-C_5, C_6-C_7	2 (0.6)
C_3-C_4, C_4-C_5, C_5-C_6, C_6-C_7	2 (0.6)
C_3-C_4, C_4-C_5, C_5-C_6	1 (0.3)
C_4-C_5, C_5-C_6, C_7-T_1	1 (0.3)
C_5-C_6, C_6-C7, C_7-T_1	1 (0.3)
C_7-T_1	1 (0.3)
Preoperative deficit	
None	238 (70.4)
Present	100 (29.6)
Material	
Cervical disc prosthesis	203 (60.1)
Blade cage	135 (39.9)

Table 3. Pre- and post-operative pain scores

VAS	**Median (Min-Max)**	**p**
Preoperative	6 (4-10)	
Postoperative 1st day	1 (0-5)	<0.001
Postoperative 3rd month	0 (0-4)	

Table 4. Comparisons of clinical characteristics between genders

	Male	Female	p
	n (%)	n (%)	
Complaint at admission			0.401
Shoulder & left arm	74 (43.3)	73 (43.7)	
Shoulder & right arm	29 (17)	33 (19.8)	
Shoulder	32 (18.7)	25 (15)	
Shoulder & both arms	27 (15.8)	25 (15)	
Both arms	2 (1.2)	6 (3.6)	
Right arm	2 (1.2)	4 (2.4)	
Left arm	5 (2.9)	1 (0.6)	
Localization			0.169
C_5-C_6	79 (46.2)	66 (39.5)	
C_6-C_7	42 (24.6)	61 (36.5)	
C_5-C_6, C_6-C_7	19 (11.1)	10 (6)	
C_4-C_5	13 (7.6)	12 (7.2)	
C_4-C_5, C_5-C_6	6 (3.5)	9 (5.4)	
C_3-C_4	4 (2.3)	4 (2.4)	
C_4-C_5, C_5-C_6, C_6-C_7	3 (1.8)	2 (1.2)	
C_4-C_5, C_6-C_7	2 (1.2)	-	
C_3-C_4, C_4-C_5, C_5-C_6, C_6-C_7	1 (0.6)	1 (0.6)	
C_3-C_4, C_4-C_5, C_5-C_6	1 (0.6)	-	
C_4-C_5, C_5-C_6, C_7-T_1	-	1 (0.6)	
C_5-C_6, C_6-C7, C_7-T_1	-	1 (0.6)	
C_7-T_1	1 (0.6)	-	
Preoperative deficit			0.537
None	123 (71.9)	115 (68.9)	
Present	48 (28.1)	52 (31.1)	
Material			0.087
Cervical disc prosthesis	95 (55.6)	108 (64.7)	
Blade cage	76 (44.4)	59 (35.3)	

Table-5. Comparisons of VAS scores between genders

VAS	Male	Female	
	Median (Min-Max)	Median (Min-Max)	p
Preoperative	6 (4-10)	6 (4-10)	0.370
Postoperative 1st day	1 (0-5)	1 (0-4)	0.891
Postoperative 3rd month	0 (0-4)	0 (0-4)	0.014

DISCUSSION

Cervical disc herniation is a common disease with pain and disability. Surgical or conservative treatment options are quite extensive [15]. A variety of surgical methods have been described. Anterior or posterior approaches could be chosen. Radiologic examinations such as Computed Tomography (CT), Magnetic Resonance Image (MRI), X ray and neurological examination findings are guiding our treatment modality choice. MRI could demonstrate degenerative disc disease in patients who older than 40 years even if they are asymptomatic [7,9]. Therefore, patient complaints and physical examination findings are important.

Many implants can be used for anterior discectomy and fusion [14,18]. Simple cage can be used for fusion. The use of cage has disadvantages such as loss of lordosis, cage extrusion, pseudoarthrosis and disc height loss. Although fusion rate is good it can cause adjacent segment disease [10,16-17]. Disc prosthesis is recommended to avoid this. Even if some authors believe that the prosthesis protects the moving segment, some do not [2,4,6,8,11-12]. Also there have been no clear evidence that the increased stress or strain of adjacent segment from the fusion which is indicated as the cause of ASD increases the incidence of reoperation. Prosthesis replacement is also introduced for reducing ASD, but from the med-long term follow-up of ACD+fusion and prosthesis replacement, it have failed to identify any significant difference in the prevalence of ASD between them. Eventually the focus on prosthesis replacement to overcome the limitation of fusion surgery could not show superiority in comparison to ACD+fusion, hence it can be an alternative to fusion surgery, but it will be hard to substitute ACD+fusion.

There are many clinical series about cervical disc herniations. Statistical results could be different because of genetic variations and enviromental factors. We search similar studies from our territory and we found that Aydoğmuş et al. had a similar clinical series [1]. When we compare with our study similar results found at the level of disc herniation, side of symptoms and type of surgery.

We try to analyse our anterior cervical discectomy operations with demographic and clinical datas. Results of these kind of clinical series demand on genetic variations, weather conditions, social and economic factors of the territories. Surgical methods can vary on surgeons experience and supportment of implant technologies.

REFERENCES

1. Aydoğmuş E, Gül A, Gür E, Kaya E, Tiryaki M, Süslü HT. Anterior cervical discectomy:Analysis of the results of two years. *JTSS* 2016; 27(3): 143-146.

2. Blumenthal SL, Ohnmeiss DD, Guyer RD, Zigler JE. Reoperations in cervical totaldisc replacement compared with anterior cervical fusion: results compiled from multiple prospective food and drug administration investigational device exemption trials conducted at a single site. *Spine* 2013; 38(14): 1177-1182

3. Conelly PJ, Esses SI, Kostuik JP. Anterior cervical fusion: outcome analysis of patients fused with and without anterior cervical plates. *J Spinal Disord*. 1996; 9(3): 202-206.

4. Eck JC, Humphreys SC, Lim TH, et al. Biomechanical study on the effect of cervical spine fusion on adjacent-level intradiscal pressure and segmental motion. *Spine* 2002; 27: 2431-2434.

5. Grob D. Surgery in the degenerative cervical spine. *Spine* 1998; 23: 2674-2683

6. Heidecke V, Burkert W, Brucke M, Rainov NG. Intervertebral disc replacement for cervical degenerative disease--clinical results and functional outcome at two years in patients implanted with the Bryan cervical disc prosthesis. *Acta Neurochir(Wien)* 2008; 150(5): 453-459.

7. Lehto IJ, Tertii MO, Komu ME, Paajanen HE, Tuominen J, Kormanu MJ. Age-related MRI changes at 0.1 T in cervical discs in asymptomatic subjects. *Neuroradiology* 1994: 36(1): 49-53.

8. Leung C, Casey AT, Goffin J, Kehr P, Liebig K, Lind B, Logroscino C, Pointillart V. Clinical significance of heterotopic ossification in cervical disc replacement: a prospective multicenter clinical trial. *Neurosurgery* 2005; 57(4): 759-763.

9. Matsumoto M, Fujimura Y, Suzuki N, Nishi Y, Nakamura M, Yabe Y, Shiga H. MRI of cervical intervertebral discs in asymptomatic subjects *J Bone Joint Surg* 1998; 80-B(1): 19-24

10. Moreland DB, Asch HL, Clabeaux DE, Castiglia GJ, Czajka GA, Lewis PJ, Egnatchik JG, Cappuccino A, Huynh L. Anterior cervical discectomy and fusion with implantable titanium cage: initial impressions, patient outcomes and comparison to fusion with allograft. *Spine J* 2004; 4(2): 184-191.

11. Parkinson JF, Sekhon LH. Cervical arthroplasty complicated by delayed spontaneous fusion. Case report. *J Neurosurg Spine* 2005; 2(3): 377-380.

12. Schwab JS, Diangelo DJ, Foley KT. Motion compensation associated with single-level cervical fusion: where does the lost motion go? *Spine* 2006; 31: 2439-2448.

13. Smith GW, Robinson RA. The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. *J Bone Joint Surg* 1958; 40A: 607-624.

14. Song KJ, Choi BY. Current concepts of anterior cervical discectomy and fusion: a review of literature. *Asian Spine J* 2014; 8(4): 531-539.

15. Süslü H, Düzkalır HG, Özdoğan S, Şenol Ö, T atarlı N, Düzkalır AH, Yaltırık CK. Flouroscopy guided transforaminal steroid injection on cervical radicular pain. *JTSS* 2015; 26(2):127-133.

16. Thomé C, Krauss JK, Zevgaridis D. A prospective clinical comparison of rectangular titanium cages and iliac crest autografts in anterior cervical discectomy and fusion. *Neurosurg Rev* 2004; 27(1): 34-41.

17. Türeyen K. Disc height loss after anterior cervical microdiscectomy with titanium intervertebral cage fusion. *Acta Neurochir* (Wien) 2003; 145(7): 565-569.

18. Xie JC, Hurlbert RJ. Discectomy versus discectomy with fusion and instrumentation: a prospective randomized study. *Neurosurgery* 2007; 61(1): 107-116.

19. Yunus A, Halit Ç. Servikal Disk Hernisi. Chapter-105. In: Korfalı E, Zileli M (Eds). Temel Nöröşirürji. Türk Nöroşirürji Derneği Yayınları No:10 Ankara 2010; p: 1461-1470.

Volume: 28, Issue: 3, July 2017 pp: 163-168 ORIGINAL ARTICLE

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CLINICAL OUTCOMES OF CAUDAL EPIDURAL STEROID INJECTIONS UNDER ULTRASOUND GUIDANCE

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Running Title: Caudal Epidural Steroid Injections Under Ultrasound Guidance

SUMMARY

Background Data: Caudal epidural steroid injections under fluoroscopy guidance have been used to relieve chronic low back pain due to lumbosacral nevre root compression. However the results of caudal epidural steroid injections under ultrasound guidance haven't been proven.

Purpose: To determine the clinical outcomes of caudal steroid injections in patients with spinal stenosis under ultrasound guidance.

Materials-Methods: A total of 298 patients with spinal stenosis scheduled to receive caudal epidural injections under ultrasound guidance. The patient characteristics were recorded. A linear array probe was used initially for each patient. The procedure was performed with a convex array probe if adequate ultrasound images could not be achieved with the linear array probe. The effect of BMI on the availability to visualize the sacral hiatus and to perform the caudal injection with either linear or convex probe was evaluated.

Results: The patients (221 women, 77 men) with mean age of 58.55±14.29 were included. Mean body mass index (BMI) was 30.99±4.29 kg/cm^2. The sacral hiatus was identified by ultrasound images using linear probe in 260 (87.24%) of patients and by convex array probe in 38 (12.76%) of patients. BMI of these patients were 30±3.6 and 37.8±1.21, respectively ($p<0.0001$). The initial NRS_0 scores, NRS scores after (NRS_1) and one month after (NRS_2) caudal epidural injection were 7.66±1.26, 3.65±1.3 and 3±1.29 ($p<0.0001$, $p<0.0001$, $p<0.0001$), respectively.

Conclusion: Ultrasonography is effective for guiding caudal epidural injection and convex array probe would be preferred in overweight patients if adequate images was not achieved with linear array probe.

Key words: Spinal stenosis, Caudal Epidural Steroid Injections, Ultrasound Guidance

INTRODUCTION

Lumbar spinal stenosis, intervertebral disc herniation, degenerative spondylolisthesis and post lumbar surgery syndrome are the most common diagnosis of low back and leg pain (7,11). Epidural injection of corticosteroids with local anesthetics is one of the most commonly used interventions for managing chronic spinal pain. Corticosteroids reduce inflammation and local anesthetics have anti-inflammatory effects as well (6).

Epidural injections are administered utilizing caudal, interlaminar and transforaminal approach. Caudal epidural injections are considered to be the least specific modality and require relatively high volumes to reach the pathologic location. However, it is the safest technique with minimal risks for inadvertent dural puncture (14). In the caudal approach, the epidural space is entered via the sacral hiatus and abnormalities and variations of the sacrum and sacral hiatus are challenges to locate the sacral hiatus in adults (15). Incorrect needle placement has been demonstrated in 20% to 38% of patients who have caudal epidural injections without fluoroscopy (12). Although fluoroscopy guidance has a failure rate of 2%, it is important to use fluoroscopy to confirm the correct needle position

and that medications are properly injected into the epidural space (5).

Ultrasound guidance has been increasingly utilized in pain management for procedures that have been traditionally performed under fluoroscopy such as epidural injections (11,9). Ultrasonograhic guidance may also help to locate the sacral hiatus and sacrococcygeal ligament and identify the anatomic variations of the sacrum and sacral hiatus and may allow caudal epidural injections to be performed easily and safely (8).

In this study we evaluated the achievability to caudal epidural space with ultrasound guidance in patients with low back and leg pain due to lumbar spinal stenosis.

MATERIAL AND METHODS

The patients with low back pain and bilateral leg pain due to spinal stenosis aged between 20 to 87 years were included and managed at Baskent University Department of Pain Medicine in Adana, Turkey during a 4 years period. A total of 298 patients (221 women, 77 men) were enrolled into the study if they had low back pain and radicular pain in the lower extremities of more than 3 month duration with no response to conservative management. The patients were fully informed of the risks and expected benefits of caudal epidural injections and provided informed consent to the procedure. Exclusion criteria were as follows: symptoms requiring emergency surgery, coagulopathy, evidence of infection and inflammation, allergy to iodinated contrast or medications and pregnancy.

The patient characteristics including age, sex, body mass index, intensity and history of pain, pain symptom characteristics and duration, presence of neurologic symptoms, neurogenic claudication, previous pharmacotherapy and physiotherapy and amount of analgesics used were recorded. Patients were asked to use a numeric rating scale (NRS) to measure average pain intensity before (NRS_0), after (NRS_1), and 1 month after the procedure (NRS_2).

Ultrasound Guided Caudal Epidural Injection Technique

The procedure was performed with the patient placed in prone position. An ultrasound machine with a 6 to 13 MHz linear array probe was used initially for each patient. The procedure was performed with a convex array probe if adequate ultrasound images could not be achieved with the linear array probe (Fujifilm Sonosite, Inc. Bothell, WA 98021 USA). The ultrasound probe was covered with sterile plastic. A wide area of back skin was cleaned with povidone-iodine and covered with a sterile drape. The transducer is first placed transversely at the midline to view the sacral hiatus. The two sacral cornua were seen as two hyperechoic structures forming a reverse U shaped structures. Between the cornua, two hyperechoic band-like structures were identified, the sacrococcygeal ligament superiorly and the sacral surface inferiorly (Figure 1). The sacral hiatus was seen as a hypoechoic region between these two band-like structures. The transducer is rotated 90 degrees between the two cornua to obtain the longitudinal view of sacral hiatus. A 22- gauge spinal needle was placed in line with the transducer and advanced into the sacral hiatus longitudinally (Figure 2). The needle shaft, passage of the needle through the ligament and presence of the needle tip entered in the sacral canal was visualized. Once proper needle placement was achieved, a mixture of 16 mg dexamethasone+20 mg bupivacaine in 20 mL was injected and turbulence of the injected material was observed in the sacral canal under ultrasound guidance (Figure 3).

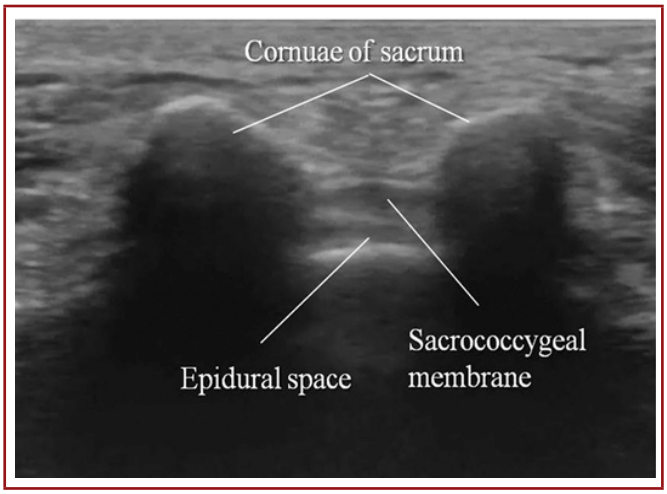

Figure 1. The view of sacral hiatus and U shaped bilateral cornua with USG probe placed transversly at the midline.

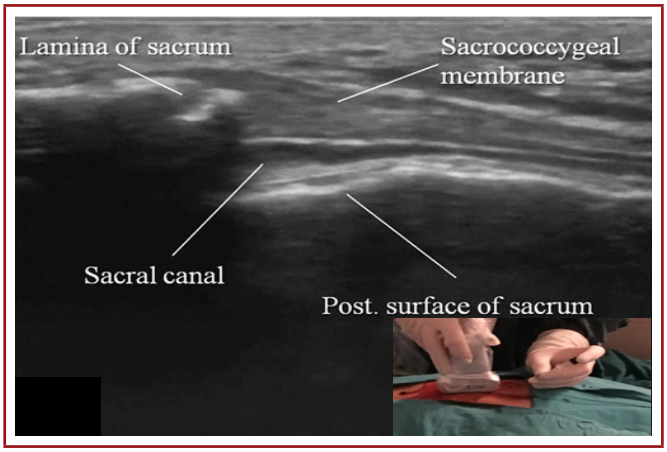

Figure 2. The longitudinal view of sacral hiatus with the transducer rotated 90 degrees between the two cornua.

Patient follow-up

An intravenous catheter was inserted into a vein of the forearm and midazolam 2 mg and fentanyl 50 µgr IV was given for sedation before caudal epidural injection and pulse oximetry

was placed for monitoring. Patients were observed for one hour after the injection in the pain clinic and adverse reactions were assessed. NRS scores were recorded and monitored for one month for both pain scores and unexpected complications.

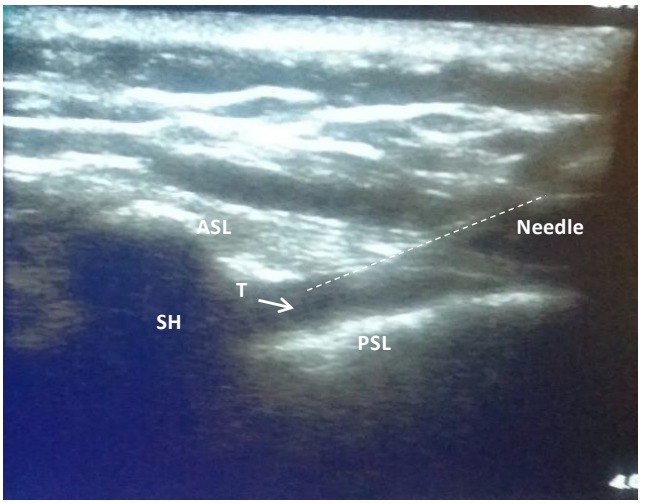

Figure 3. Proper needle placement and turbulence of the injected material in the sacral canal under ultrasound guidance SH: Sacral hiatus, T: Turbulence ASL: Anterior sacrococcygeal ligament, PSL: Posterior sacrococcygeal ligament

Statistical Analysis

Data were presented as means with standard deviation (SD) or numbers and percentages. Categorical data were analyzed with χ^2 test when appropriate. Differences between NRS were analyzed with paired sample t-test for repeated measures. The significance between BMI and the success of the procedure with each ultrasound probe were assessed by ANOVA. Data analyses were conducted using SPSS for Windows, version 17.0 (SPSS Inc., Chicago, IL, USA). P<0.05 was considered statistically significant.

RESULTS

We included 298 patients (221 women and 77 men) with a mean age of 58.55±14.29 (range, 20-87 years). Mean body mass index was 30.99±4.29 kg/cm^2 (range, 18.5-41 kg/cm^2). According to the BMI categorization 56.4 % (n=168) of patients were overweight or obese (BMI > 25). The patient characteristics are listed in Table 1. The initial NRS_0 scores were 7.66±1.26 and pain durations were 13.21±19.05 months. Pain was constant in 72.1% (n=215) of patients. Neuropathic symptoms and neurogenic claudication were described in 73.8% (n=220) and 20.1%(n=60) of patients, respectively. The trajectory of nerve root pain due to spinal stenosis was determined for 1 level in 65 (21.8 %) patients, for 2 levels in 90 (30.2 %) patients and for more than 2 levels in 143 (48 %) patients.

The sacral hiatus was identified by ultrasound images using linear probe in 260 (87.24%) of patients. In the remaining patients (38, 12.76%), ultrasonographic view with linear probe failed to confirm proper sacral hiatus images due to the inadequate depth of probe view. In these patients convex array probe was used and adequate visualization of sacral hiatus was achieved. In these patients BMI was 37.8±1.21 (36-41) whereas BMI of the patients whose sacral hiatus were visualized successfully with linear array probe was 30±3.6 (18.5-35.9)(p<0.0001).

The NRS scores immediately (NRS_1) and one month after (NRS_2) caudal epidural injection were 3.65±1.3 and 3±1.29, respectively and were significantly lower than NRS_0 scores (p<0.0001, p<0.0001, respectively). Neuropathic symptoms were completely resolved in 64.1% (n=191) of patients. Medical therapy was continued in 26.8% (n=80) of patients. Neuropathic symptoms, analgesic consumption and physiotherapy requirements were significantly decreased 1 month after caudal epidural injection (p<0.0001, p<0.0001, p<0.0001, respectively). Fourteen patients (4.7%) underwent surgical treatment due to unrecovered symptoms of spinal stenosis after caudal epidural injection.

Table-1. Patient characteristics

	n (%)
Neuropathic symptoms	220 (73.8%)
Neurologic deficit	51 (17.1%)
Neurogenic claudication	60 (20.1%)
Physiotherapy	112 (37.6%)
Surgery	52 (17.4%)
Pain	
Continuous	215 (72.1%)
With motion	76 (25.5%)
During rest	7 (2.3%)
Analgesic therapy	
No	77 (25.8%)
NSAIDs, n (%) of patients	107 (35.9%)
Adjuvants, n (%) of patients	38 (12.7%)
NSAIDs + Adjuvants, n (%) of patients	166 (55.7%)

NSAIDs: nonsteroidal anti-inflammatory drug

DISCUSSION

Caudal epidural injections in patients with spinal stenosis with low back and lower extremity pain provide significant pain relief and improvement in functional status (2). Caudal injections although are not superior to either interlaminar or transforaminal, may provide equal effectiveness (4). Fluoroscopic real-time guidance has been used to confirm

proper needle position in the sacral canal for caudal epidural injection and approximately a total volume of 20 mL is injected to sufficiently fill the epidural space up to the lumbar vertebras with a descending degree (6).

Ultrasound could also be an effective guidance during caudal injection without the risk of radiation. It is appropriate for both monitoring the needle insertion and advancement into the caudal epidural space, the turbulence of injected volume and it's proximal spread through the sacral canal. The success rate of caudal epidural injection under ultrasound has been reported 95.8% and 96.6% in two studies (13,1). In these studies body landmarks were assessed with linear-array probes and the high success rates were correlated with detecting the bilateral sacral cornua, apex of the sacral hiatus, anterior and posterior walls of the sacral canal and sacrococcygeal ligament clearly.

In our study, all caudal epidural injections could be performed under ultrasound guidance. However, with linear-array probe the sacral hiatus was identified in 87.24% of patients. In 12.76% of patients, linear probe failed to confirm proper sacral hiatus images due to the inadequate depth of view. In these patients adequate visualization of sacral hiatus was achieved with convex array probe. The main significant difference between these patients was BMI. The BMI of patients whose sacral hiatus were visualized successfully with linear array probe was 30±3.6 (18.5-35.9) and with convex array probe was 37.8±1.21 (36-41).

In previous studies the procedure was performed with high success rates and the BMI were 27.18±4.8 and 27.19±6.7, respectively (13, 1). In another study, clear ultrasound images of the sacral hiatus was obtained in patients with a BMI range of 23-27 kg/cm^2 (3). In our study, mean BMI of patients was higher than these previous studies and, linear-array probe was sufficiently used in patients with a maximum BMI of 35.9 kg/cm^2. However, in patients with a BMI ≥36 kg/cm^2, the anatomical details of the sacral hiatus was invisible due to excessive fat tissue overlying the sacrum. Then we changed the linear probe with convex array to achieve an adequate dept of view and obtain clear ultrasound images of sacral hiatus. Also, in another study, ultrasonography was failed to identify the sacral hiatus with linear probe in one of 30 patients who had a BMI, 46 kg/cm^2 (1).

The anatomic variations of the sacral hiatus are the main predictors of the success of caudal injections. In anatomic studies, the sacral hiatus is usually described using two measurements, the distance between the sacral cornua tips and the diameter of the canal at the apex of the hiatus. The anatomic variations of these landmarks are suggested to change the safety and success rate of the caudal injections based on radiologic or cadaveric measurements (10). Additionally, the optimal angle of needle insertion and the depth of the caudal space are mainstays of anatomical landmarks.

According to our results, except anatomical variations or substantial closed sacral hiatus, BMI of patients indirectly effected the success rate of the procedure under ultrasound guidance due to excessive sacral fat tissue. This would not be the cause of difficulty or unsuccessfulness of the procedure under fluoroscopy guidance. However, to obtain adequate depth of caudal space view with sacral hiatus images under ultrasound guidance, convex array probes should be used instead of linear probes.

CONCLUSION

Ultrasonography is effective for guiding caudal epidural injection and we suggest that convex array probe would be the first option if the patient's BMI is greater than 36 kg/cm^2 or would be changed to if adequate image was not achieved with linear array probe due to the depth of caudal space.

REFERENCES:

1. Blanchais A, Goff BL, Guillot P, Berthelot JM, Glemarec J, Maugars Y. Feasibility and safety of ultrasound-guided caudal epidural glucocorticoid injections. Joint Bone Spine 2010;77:440-444.
2. Chen CP, Tang SF, Hsu TC, et al. Ultrasound guidance in caudal epidural needle placement. Anesthesiology 2004;101:181-184.
3. Chen CP, Wong AM, Hsu CC, et al. Ultrasound as a screening tool for proceeding with caudal epidural injections. Arch Phys Med Rehabil 2010;91(3):358-363.
4. Conn A, Buenaventura R, Datta S, Abdi S, Diwan S. Systematic review of caudal epidural injections in the management of chronic low back pain. Pain Physician 2009;12:109-135.
5. el-Khoury GY, Ehara S, Weinstein JN, et al. Epidural steroid injection: a procedure ideally performed with fluoroscopic control. Radiology 1988;168:554-557.
6. Ghai b, Kumar K, Bansal D, Dhatt SS, Kanukula R, Batra YK. Effectiveness of parasagittal interlaminar epidural local anesthetic with or without steroid in chronic lumbosacral pain: A randomized, double-blind clinical trial. Pain Physician 2015;18-237-248.
7. Katz JN, Harris MB. Clinical practice. Lumbar spinal stenosis. N Engl J Med 2008; 358:818-825.
8. Klocke R, Jenkinson T, Glew D. Sonographically guided caudal epidural steroid injections. J Ultrasound Med 2003;22:1229-1232.
9. Lewis MP, Thomas P, Wilson LF, Mulholland DC. The 'whoosh' test. A clinical test to confirm correct needle placement in caudal epidural injections. Anaesthesia 1992;47(1):57-58.

10. Macchi V, Porzionato A, Morra A, Stecco C, De Caro R. Radiologic anatomy of the sacral canal. Acta Neurochir Suppl. 2011;108:5-8.

11. Manchikanti L, Cash KA, McManus CD, Pampati V, Fellows B. Results of 2-year follow-up of a randomized, double-blind, controlled trial of fluoroscopic caudal epidural injections in central spinal stenosis. Pain Physician 2012;15:371-384.

12. Manchikanti L, Cash KA, Pampati V, et al. Evaluation of fluoroscopically guided caudal epidural injections. Pain Physician 2004;7:81-92.

13. Nikooseresht M, Hashemi M, Mohajerani SA, Shahandeh F, Agah M. Ultrasound as a screening tool for performing caudal epidural injections. Iran J Radiol 2014;11(2):e13262.

14. Parr AT, Manchikanti L, Hameed H, et al. Caudal epidural injections in the management of chronic low back pain: A systematic appraisal of the literature. Pain Physician 2012; 15:E159-E198.

15. Yoon JS, Sim KH, Kim SJ, et al. The feasibility of color doppler ultrasonography for caudal epidural steroid injection. Pain 2005;118:210-214.

Volume: 28, Issue: 3, July 2017 pp: 169-174 ORIGINAL ARTICLE

ALTERING OF CERVICAL SAGITTAL PARAMETERS AFTER 1 OR 2 LEVELS ANTERIOR CERVICAL DISCECTOMY AND FUSION WITH LORDOTIC CAGES. SHORT TERM RESULTS.

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SUMMARY

Objective: To investigate changings of cervical sagittal parameters after anterior discectomy and fusion (ACDF) with lordosis cages.

Material and methods: This study includes 55 patients with one and two levels of soft cervical disc hernia who were operated via ACDF with lordosis cage. The study is designated retrospectively. Visual analog scale (VAS) values, cervical lordosis angle, cranial slope and C_2 tilt were evaluated preoperatively and postoperatively at some certain periods. Changings of these parameters compared statistically. Correlation between VAS values and sagittal parameters were investigated statistically.

Results: No statistically significant differences were found between preoperative and postoperative sagittal parameters. Statistical analysis showed that change of VAS values is significant for every level and two levels disk hernia for all postoperative follow-up times ($p<0.001$).

Conclusions: Restoration of cervical sagittal parameters measurements come closer those of normal population values after surgery. However, these changings were not statistically significant. The clinical results of surgical treatment of cervical disc disease generally come before radiological improvement like other areas of spinal surgery. It is expected that statistically significant results can be obtained from long term follow-ups since these parameters approaching the values of normal population in the early postoperative period.

Key words: Anterior cervical discectomy and fusion, cervical sagittal parameters, lordotic intervertebral cage

Level of Evidence: Retrospective clinical study, Level III

INTRODUCTION

It is widely accepted that cervical degenerative disc diseases (CDDD) occurs in some degenerative background. These degenerative cervical changes result in cervical sagittal malalignment [2,14,15]. This study emerges from the idea that after removing degenerative disc material surgically and decompressing the neural tissue, sagittal profile can be restored to the similar values those of normal population [12]. The secondary opinion of the study is to use lordosis cage for facilitating this restoration. A radiographic study designated from this point of view. Cervical sagittal alignment is commonly assessed by calculating cervical lordosis and some other related metrics that gives slope of the head or proximal thoracic region [11,15]. Because the cervical spine is the most mobile part of the spinal column, a wide range of normal alignment has been described [5]. Value and the center of cervical lordosis are the main basis of cervical sagittal alignment measurements [10].

The main aim of this study is to show whether radiographic sagittal restoration occurs or not after anterior cervical discectomy with fusion (ACDF) with a lordosis cage for CDDD. This study gives short-term results.

MATERIAL AND METHODS

After obtaining an approval from Düzce University Committee on Ethics for Non-interventional Health Studies (16 Jan, 2017-2017/01), retrospectively designated study began.

Study includes 55 patients who were performed ACDF with a lordosis cage in between 2015 and 2017 in Düzce University Hospital. Patients were between 18 and 70 years old men and women with one or two levels of soft cervical disc herniation's (CDH) that were performed ACDF after the failure of 3 weeks of medical treatment.

Including criteria

1. Men and women between 18 and 70 years old with 1 or 2 levels soft CDH that were performed ACDF after the failure of 3 weeks of medical treatment.
2. Patients who have symptoms were relevant to their radiological imaging studies were included in the study.
3. Excluding criteria
4. Patients who have cervical spondylosis, olisthesis, spondylotic myelopathy and foraminal bony narrowing;
5. Patients who were performed operation for cervical region for any reason;
6. Patients who have traumatic disc hernia or any traumatic condition affecting cervical region;
7. Patients who have cervical congenital anomalies or malformations such as Klippel Feil anomaly or Chiari malformation;
8. Patient who have severe metabolic diseases such as diabetes or chronic obstructive pulmonary diseases;
9. Patients who have malignant diseases, and already had chemotherapy or radiotherapy are excluded from the study.

All patients were performed detailed neurological examination and obtained visual analog scale (VAS) scores preoperatively, postoperatively on the 1st day, 15th day and the 3rd month.

Radiographic measurements

All patients were performed standing lateral cervical roentgenograms preoperatively, postoperatively on the 1st day, 15th day and the 3rd month. Sagittal parameters were measured on these roentgenograms. Cervical lordosis angle (CL) (Fig. 1), C_2 tilt angle (C_2T) (Fig. 2), and Cranial slope (CS) (Fig. 3) values were obtained at all of these follow-up times.

1. CL: Angle between the line parallel to the C2 posterior margin and the line parallel to the C7 posterior margin [3].
2. C2T: Angle between the vertical line passing through the center of C7 and a line passing through the center of the lower end plate of C2 and the center of C7 [8].
3. CS: Angle between the horizontal line and the McGregor line [8].

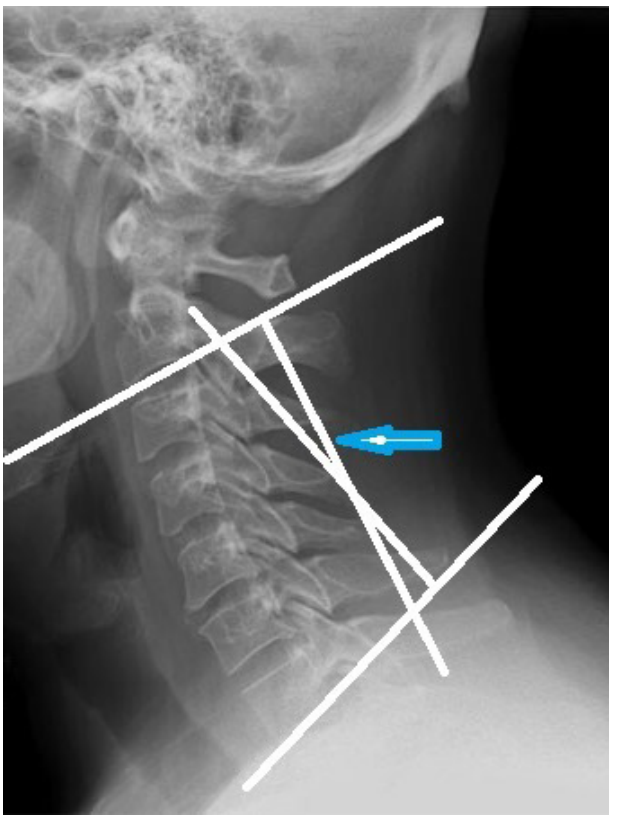

Figure-1. CL angle measurement by Cobb method.

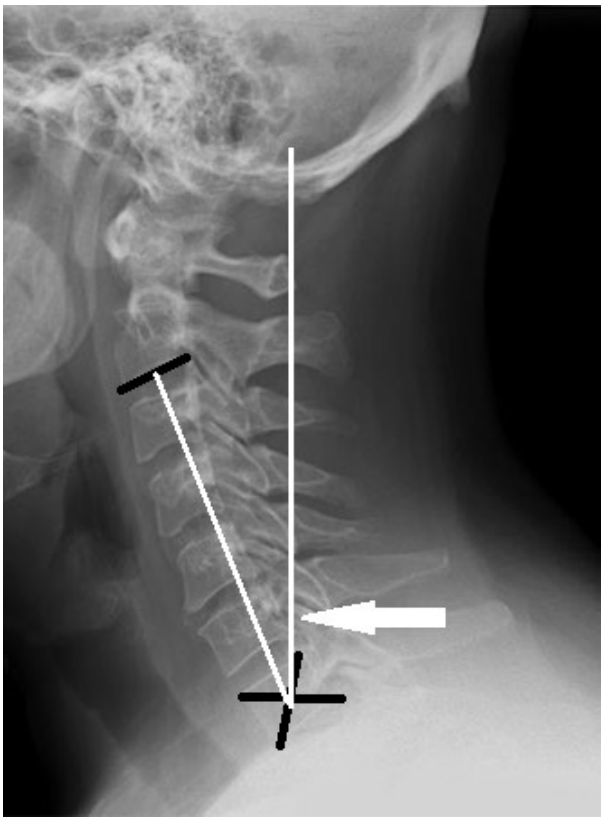

Figure-2. C2T angle measurement is shown.

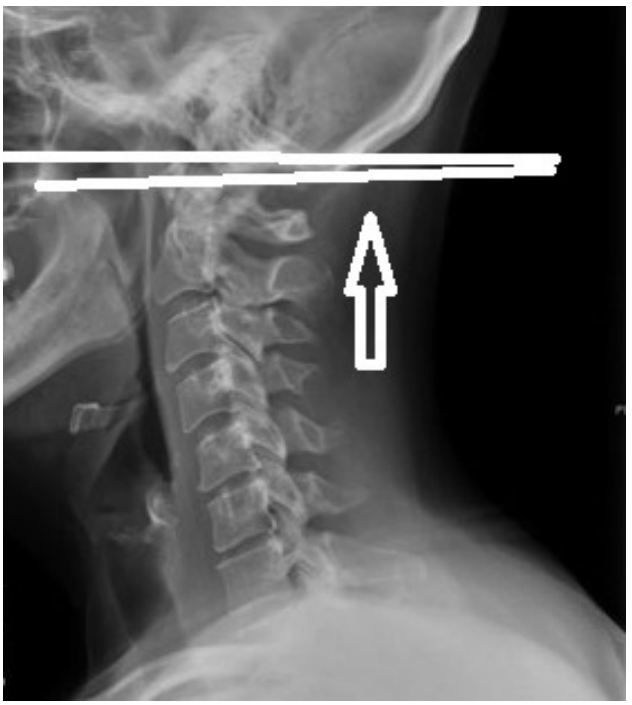

Figure-3. CS measurement.

Operation technique

ACDF is the treatment of choice for cervical disc herniation and spondylotic radiculopathy or myelopathy [9]. The patient is placed in the supine position with the neck slightly extended. The patient's head is fastened in the table with tape to maintain a neutral position, and his or her shoulders are tightened down with tape for allowing appropriate visualization with C-arm image intensifier. A right-side transverse 2 cm skin incision is done, platysma muscle is opened transversely. To reach to the anterior of the cervical vertebral column, dissection is advanced from the lateral edge of the M. sternocleidomastoid. Internal carotid artery and trachea-esophagus are retracted laterally and medially respectively. After fluoroscopic localizing, discectomy is performed by microinstruments under the operating microscope (Zeiss OpMi Pentera 900, 2012, Jena, Germany). After curettage of both endplates, a proper allograft (Demineralized Bone Matrix) filled PEEK cage (Polyether ether ketone Lor X® Cervical Peek cage with blade, TiGA14V ELI alloy, 0,3 mm tread depth, with 1,5 mm blades, 5º lordotic, static resistance of 15 kN/mm, dynamic strength of 100N / 1.000.000 cycles) inserted in the intervertebral space.

Statistical analysis

Changings of all parameters with time after operation were evaluated and compared with corresponding VAS scores. Descriptive statistics of whole data were analyzed. Normality assumptions of continuous variables were tested by Kolmogorov Smirnov test. Comparing changing of variables at follow-up times were tested by Friedman (post hoc: Bonferroni adjusted Wilcoxon test), Paired Samples t test and Wilcoxon tests. When the p values were less than 0.05, changing was accepted as statistically significant.

RESULTS

Patients' demographics

Thirty male (54.5%) and 25 female (45.5%) patients were included in the study. Mean age of the patients was 45.4 years old (27-67 years old).

Thirty-seven of the patients (67.2%) were operated for one level, 18 (32.7%) of them were operated for 2 levels CDH. The majority of the patients had an only one level CDH at the C5-6 level (41.8%). On the other hand, CDH at the C5-6 level was found in 70.9% of all patients (Table-1).

Table-1. CDH levels and frequency.

CDH levels	n	%
One level	37	67.3
C3-4	1	1.8
C5-6	23	41.8
C6-7	13	23.6
Two levels	18	32.7
C3-4 and C5-6	1	1.8
C3-4 and C6-7	1	1.8
C4-5 and C5-6	5	9.1
C4-5 and C6-7	1	1.8
C5-6 and C6-7	10	18.2
Total	55	99.9

Table-2. VAS scores and statistical results.

VAS scores	Mean±SD	Median	Min.	Max.	p
Preop.	6.76±1.07	7.00	5.00	9.00	< .001
Postop. 1st day	3.78±1.15	4.00	1.00	5.00	< .001
Postop. 15th day	2.62±1.35	3.00	.00	6.00	< .001
Postop. 3rd month	1.82±1.26	2.00	.00	5.00	< .001

Table-3. Changings and statistical results of radiographic measurements of sagittal parameters.

Sagittal parameter	Mean±SD	Median	Min.	Max.	p
CL preop.	8.9±6.6	6.7	.4	25.6	.285
CL postop.	9.8±8.3	7.2	-19.2	33.2	.285
C_2T preop.	12.9±4.9	11.2	2.9	22.1	.421
C_2T postop.	14.1±13.7	12.8	2.5	24.3	.421
CS preop.	9.7±5.6	8.3	1.0	23.7	.806
CS postop.	10.0±6.7	8.7	1.2	33.4	.806

All values are given as (°).

VAS scores

The VAS scores of the patient for preoperatively and all the follow-ups are shown in the Table-2. The mean VAS value is 7.0, 4.0, 3.0 and 2.0 preoperatively, on the 1st day, 15th day and 3rd month postoperatively respectively. Changing in time for VAS values is statistically significant for all the follow-up times (p<0.001 for each).

Radiographic measurements of sagittal parameters

Statistical analyses of changing of the sagittal parameters are given by the table 3. There is no statistically significant changing of sagittal radiologic measurements (Table-3). The maximum different values were used for postoperative values. These values were generally obtained on the postoperative 3rd month.

DISCUSSION

When the "pain" is considered as the main complaint, patients of the series of this study were improved after ACDF due to their postoperative VAS scores only, and changings of VAS grades. Decrease of the mean VAS score at the very early postoperative period, on the 1st day, is exceedingly impressive. The mean VAS score was 6.76 and 3.78 preoperatively and on the 1st day respectively. This result is statistically significant (p< .001). The importance of this result is that it indicates the main problem of patients with CDH. Extremely good recovery on the 1st postoperative day is the result of decompression of the neural tissue. Some studies in literature supports this idea [3,13]. Neural compression is the most crucial factor to develop symptomatology of CDH. It can be statistically claimed that ACDF operation is a very suitable choice of the treatment of the patients with 1 or 2 levels soft CDH according to mean VAS scores on the 15th day and 3rd month, 2.62 and 1.82 respectively. The p values are less than 0.001 on both follow-up periods. Continuing decrease of VAS scores at the postoperative period may be indicative of ongoing healing of the neural tissue after decompression.

Maximum recovery is seen very early postoperative period, but healing is continuing for a reasonable long time. When using median instead of mean as a statistical parameter, the condition doesn't change; p is less than 0.001 for every follow-up time. The median VAS decreased from 7.00 preoperatively, to 4.00, 3.00 and 2.00 postoperatively on the 1st, 15th days and 3rd month respectively. Location or multiplicity of the CDH doesn't make change VAS changings statistically. Changing is from preoperatively 7.0 to postoperatively 5.0 for C3-4 hernias; from 7.4 to 1.9 for C5-6 hernias; from 6.2 to 0.7 for C6-7 hernias and from 6.8 to 1.9 for two level hernias. Result of C3-4 hernia seems to anomalous outcome. But there is only one C3-4 CDH in the series, so its result is expected as statistically insignificant in all circumstances. Normal populations data about these parameters are given in the literature [4,8,16]. Normal values of CL, C2T and CS are 4.89°±12.84°, 10.48°±6.93° and 1.59°±6.81°.

The vital consequence of this study is that the results don't support the main hypothesis of the study which stated that the changings of the cervical sagittal parameters will be parallel to the recovery rate of patients. When the study designated, investigations of two main clinical predictions were considered. Is there any correlation between sagittal cervical parameters and symptomatology of CDH? And, can normalizing of sagittal parameters be provided after decompression of neural tissue via ACDF [6]? These two interdependent hypotheses are not confirmed by the result of this study.

Many factors may take place for happening of this result. A short follow-up time is a crucial weakness. Although it is not statistically significant, postoperative values of the radiographic measurements changed toward the values those of normal population's. This fact gives expectations about long term results. The second central fact which emerges these results that may be acknowledged of the CDDD develops in the disordered cervical sagittal profile. Preoperative sagittal measurements especially CL of some patients were within normal limits. Besides, despite well recovery due to their VAS values, some patient's sagittal parameters were getting worse after operation. It is widely accepted that cervical paravertebral muscle spasm is the reason of cervical spinal flattening [1]. And this spasm is an important component of the patient's pain [7]. The vital question is whether this paravertebral spasm is a structural phenomenon

or a reaction to degenerative changes. The certain way to understand this is to see the lateral cervical roentgenograms of patients with CDH before they become symptomatic! It is almost impossible practically! Since CS and C_2T are the parameters directly correlated with CL, all of these opinions are valid for CS and C_2T at the same time.

Another limitation of this study is that this is a retrospectively designated investigation. More circumstances can be controlled with a prospectively designated study.

That using a lordotic cage for all patients is one of a strong point of this study. It may be added a group of straight cage for a control to the study. This can measure the contribution of lordotic cage. But this is beyond of the scope of this study.

CONCLUSIONS

ACDF is a very beneficial choice for treatment of soft CDH. It is expected that cervical sagittal parameters normalize parallel to recovery of patients after ACDF operation. Some prospectively designated studies with long term results are required.

CONFLICT OF INTEREST

The authors of this manuscript declare that there is no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

REFERENCES

1. Beltsios M, Savvidou O, Mitsiokapa EA, Mavrogenis AF, Kaspiris A, Efstathopoulos N, Papagelopoulos PJ. Sagittal alignment of the cervical spine after neck injury. *Eur J Orthop Surg Traumatol* 2013; 23 (Suppl-1): S47-51.
2. Canavese F, Turcot K, De Rosa V, de Coulon G, Kaelin A. Cervical spine sagittal alignment variations following posterior spinal fusion and instrumentation for adolescent idiopathic scoliosis. *Eur Spine J* 2011; 20: 1141–1148.
3. Dağlı M, Er U, Şimşek S, Bavbek M. Late results of anterior cervical discectomy and fusion with interbody cages. *Asian Spine J* 2013; 1: 34-38.
4. Gore DR, Sepic SB, Gardner GM. Roentgenographic findings of cervical spine in asymptomatic people. *Spine* 1986; 11(6): 521-524.
5. Gore DR. Roentgenographic findings in the cervical spine in asymptomatic persons: a ten-year follow-up. *Spine* 2001; 26: 2463-2466.
6. Gulsen S. The Effect of the PEEK Cage on the Cervical Lordosis in Patients Undergoing Anterior Cervical Discectomy. *Macedonian J Med Sci* 2015; 3(2): 215-223.
7. Helliwell PS, Evans PF, Wright V. The straight cervical spine: does it indicate muscle spasm? *J Bone Joint Surg Br* 1994; 76(1): 103-106.
8. Le Huec JC,Demezon H, Aunoble S. Sagittal parameters of global cervical balance using EOS imaging: normative values from a prospective cohort of asymptomatic volunteers. *Eur Spine J* 2015; 24: 63–71.
9. Huang ZY, Wu AM, Li QL, Lei T, Wang KY, Xu HZ, Ni WF. Comparison of two anterior fusion methods in two-level cervical spondylosis myelopathy: a meta-analysis. *BMJ Open* 2014; 4(7): e004581.
10. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. *Spine* 1994; 19: 1611–1618.
11. Janusz P, Tyrakowski M, Kotwicki T, Siemionow K. Cervical sagittal alignment in Scheuermann disease. *Spine* 2015; 40(23): E1226-1232.
12. Lee JH, Lee SH. Clinical and radiographic changes after percutaneous endoscopic cervical discectomy: A long-term follow-up. *Photomed Laser Surg* 2014; 32(12): 663-668.
13. Peolsson A, Öberg B, Wibault J, Dedering Å, Zsigmond P, Bernfort L, Kammerlind AS, Persson LC, Löfgren H. Outcome of physiotherapy after surgery for cervical disc disease: a prospective randomised multi-centre trial. *BMC Musculoskelet Disord* 2014; 15: 34.
14. Pereira SN, Hitzl W, Bullmann V, Meier O, Koller H. Sagittal balance of the cervical spine: an analysis of occipitocervical and spinopelvic interdependence, with C-7 slope as a marker of cervical and spinopelvic alignment. *J Neurosurg Spine* 2015; 23: 16–23.
15. Scheer JK, Tang JA, Smith JS, Acosta FL, Prosoptalhis TS, Blondel B, Bess S, Shaffrey CI, Deviren V, Lafage V, Schwabb F, Ames CP, and The International Spine Study Group. Cervical spine alignment, sagittal deformity, and clinical implications. *J Neurosurg Spine* 2013; 19: 141–159.
16. Yukawa Y, Kato F, Suda K, Yamagata M, Ueta T. Age-related changes in osseous anatomy, alignment, and range of motion of the cervical spine. Part I: Radiographic data from over 1,200 asymptomatic subjects. *Eur Spine J* 2012; 21: 1492–1498.

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SPINAL SURGERY COMPLICATED WITH SOME CONGENITAL AND CHILDHOOD NEURAL DISEASES

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SUMMARY

Objective: This study was a retrospective clinical research based on challenging cases with clinical and radiological data analysis, and the review of literature. The aim of this study was to determine the factors affecting spinal deformity treatment in patients with diseases of the central nervous system following neurosurgical management.

Material and Methods: Three sample cases presented and the relevant literature were interpreted by the lights of these analyses. Patients are consisted of 20 and 44 years old females and 9 years old boy with childhood neural diseases. These accompanying diseases were detected during evaluation for spinal surgery by neurologic examination and imaging modalities.

Results: All patients have been doing neurologically well with almost no deficits and manageable pain problems. A 44-year-old women who had CSF diversion operation previously, was resolved her arachnoiditis by extending the cervical stenosis operation. Neurofibromas that complicated kyphosis operation of a 9-year-old boy were removed. And tethered cord of a 20-year-old girl was untethered during scoliosis operation. All patient's neurological status is well after operations and follow-ups.

Conclusions: Surgical treatment of patients with spinal diseases may become a quite challenging case when they have congenital anomalies or CNS related problems. Staging surgical approach should be kept in mind for these kinds of patients. Besides, growing of spine and spinal cord at different rates shouldn't be forgotten for children. The whole spinal axis must be kept under lifetime control by some regular intervals for spine patients with additional congenital or CNS anomalies.

Key Words: Congenital spinal diseases, Congenital neurologic diseases, Deformity, Degenerative spinal diseases, Intraspinal anomalies, Neurofibromatosis-I, Spinal operations

Level of Evidence: Retrospective clinical trial based on a case study, level IV

INTRODUCTION

Spinal surgery has been doing in huge amount all around the world. Some diseases of the brain and spinal column are seen frequently at younger ages, children or early childhood. Congenital anomalies and diseases of the craniospinal system are expected to affect these groups of patients more than those of the older patients, and may also be associated with an increased risk for subsequent neurological compromise during spinal surgeries. Those pediatric patients are already vulnerable to any kind of surgery; associated anomalies of those patients may increase the risk of surgery. At the same time, it may be encounter some technical difficulties during surgery in older age group of patients that have some associated congenital anomalies [(1)].

The aim of the study is to reveal that how congenital spinal anomalies effect the outcomes of spinal surgery, to discuss decision making process of three sample cases. Besides, a review of the literature was executed using PubMed database. The objective of this research was to find any publication about that how congenital spinal anomalies influence the decision, and prognosis of spine surgery.

MATERIALS AND METHODS

The authors presented three of their patients who needed excessive evaluation and investigation with a lot

of preoperative tests and studies before making a decision of patients' treatment plans. Three of our patients are discussed in this manuscript. Twenty and 44 years old females and a 9-year-old boy with some spinal disorders complicated with childhood neurologic diseases are evaluated and discussed. Neurological diseases of the patients need extra surgical effort, longer surgery time or extension of operation. These associated diseases are explained in sample cases. This study is a retrospectively case analysis, so it needn't any ethics committee approval.

Sample Cases:

Case 1:

The patient was a 44-year-old woman admitted to our clinic in 2007. Her complaints were headache and severe, increasing pain in her right arm for almost 4 years. When she was 22 years old, she had a ventriculoperitoneal (V/P) shunt operation in another clinic with the diagnosis of hydrocephalus. At the night of operation a left hemiplegia developed with loss of consciousness. She had been hospitalized more than 2 months with one month in intensive care unit (ICU). In a year, her hemiplegia had been resolved by an intense physical therapy and rehabilitation. Since then she has some complaints such as moderate to severe headache, pain in her neck and especially right arms. She connected with many doctors and she had a lot of cranial magnetic resonance imagings (MRIs) including cerebrospinal fluid (CSF)-flow sequences. She was done lumbar puncture to measure the CSF pressure in another hospital few years ago, and she was hospitalized due to severe headache, and vomiting. Her last MRI revealed a right parieto-occipital calcified epidural/subdural hematoma, moderate enlargement of lateral and third ventricles with ventricular catheter on the right ventricle (Figure-1), and CSF flow in the aqueductus Silvius was in normal ranges and patterns. Her neurological examination disclosed that monoparesis of the right arm, hypoesthesia on C4,5,6,7 dermatomes. Deep tendon reflexes of all extremities were hyperactive. Hoffmann reflex was bilaterally positive, Achilles clonus and, Babinsky reflex were positive on the right side. Right shoulder impingement was also detected during abduction and external rotation. A cervical MRI was performed showing C3-4, C4-5 and C5-6 severe spondylosis with C4-T1 arachnoid cysts compressing the spinal cord especially on the right side (Figure-2). Further evaluation and tests were performed such as electromyoneurography (EMG), somatosensory evoked potentials (SSEP), and motor evoked potentials (MEP) showing myelopathy and multilevel radiculopathies. A roentgenogram showed distal catheter breakage of V/P shunt (Figure-3). Ophthalmological examination revealed that bilaterally mild optic atrophy. V/P shunt reservoir tapping was done. The CSF pressure was low, but spontaneous CSF flow through the needle was seen. Because of the possibility of partially obstruction of ventricular catheter, it couldn't be a reliable index of measuring CSF pressure for this patient. So, we decided to explore the arachnoid cyst first, because her complaints seemed mainly related with cervical compression. We explained to the patient and her family underlining that there was a risk of herniation during laminectomy and cervical dural opening. A written consent was taken for that the patient may have needed exploration of her shunt, and/or insertion of an external ventricular drainage system. C4 and C5 total laminectomy and C6 superior hemilaminectomy were performed. During the operation it was seen that there was no a single cyst, it was like arachnoiditis, with a lot of membranes firmly attached to the spinal cord and the dura forming honeycomb appearance. It was thought that arachnoiditis was caused by hemorrhages from V/P shunt insertion 22 years ago. After operation, most of her complaints were resolved mostly due to surgical decompression and duroplasty enlarging medullary canal.

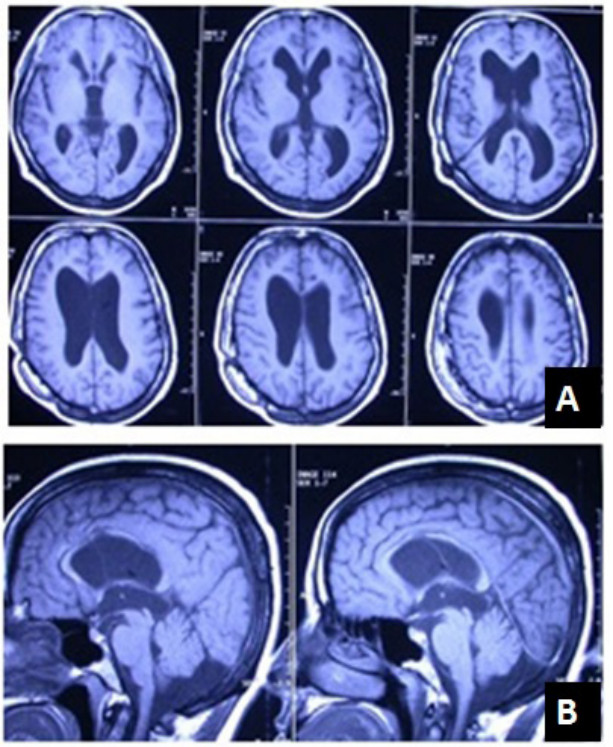

Figure-1. T1 weighted axial **(A)** and sagittal **(B)** MR images showing right parieto-occipital calcified epidural/subdural hematoma, moderate enlargement of lateral and third ventricles with ventricular catheter on the right ventricle, and normal-sized fourth ventricle.

Since the first operation she has been under follow-up routinely. Almost for 5 years she has been quite well. In 2013 she hospitalized again with the similar complaints. Her neurological examination was revealed that right-sided hemihypoesthesia, and hemiparesis (both symptoms heavy on the right arm), hyperactive deep tendon reflexes, bilateral positive Hoffman

reflex, bilateral Achilles clonus, and Babinsky reflex. There was still impingement syndrome of the right shoulder. Cranial and cervical MRIs were performed again. There was no new lesion in the cranial MRI; and the cervical MRI showed that the spondylosis and the cystic enlargement continued (Figure-4). 3D CSF flow MRI (1) was performed and showed CSF flow through the aqueductus Sylvius, Foramen of Magendie, and spinal subarachnoid spaces (Figure-5). The patient underwent operation again. Under intraoperative neuromonitoring (IONM), three level anterior cervical discectomies, corpectomies (C3-4,C4-5,C5-6), interbody cage and bony fusion with DBM and instrumentation with anterior cervical plate were performed. Then the patient was turned to prone position. Bilateral C4,5,6 lateral mass screws were inserted, C3,6,7 total laminectomies, and T1 superior hemilaminectomy were done. Dura was opened, it seemed that the arachnoiditic appearance was resolved, and there were fewer adhesions. The thick arachnoid band at superior T1 level (Figure-6) was opened and the cyst marsupialization was done. After dural closure, the posterior instrumentation and bony fusion were completed (Figure-7). At the 6th month of follow-up with physical therapy and rehabilitation program, her complaints resolved very well. She had no hemiparesis, and decreasing hemihypoesthesia. Babinsky, and Achilles clonus were disappeared on her left side. She is still under follow-up.

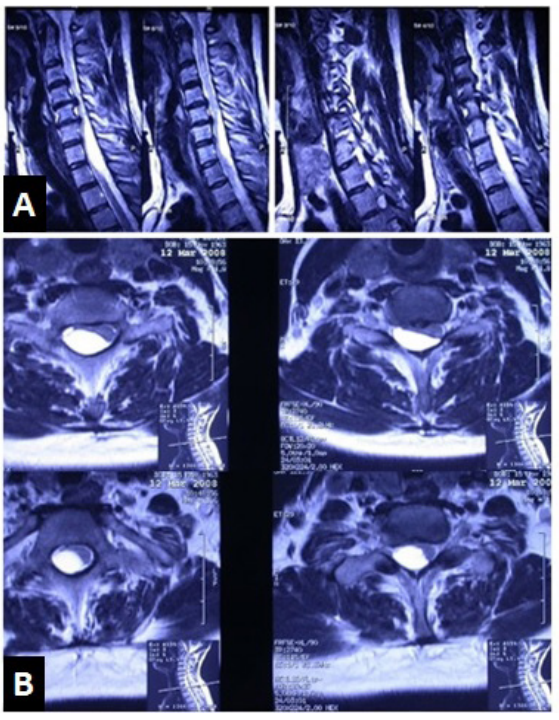

Figure-2. T2 weighted sagittal **(A)** and axial **(B)** cervical MRI showing C3-4, C4-5 and C5-6 severe spondylosis with osteophytic supur formation causing foraminal narrowing, and C4-T1 arachnoid cysts compressing the spinal cord especially on the right side.

Figure-3. PA abdominal x-ray showed distal catheter breakage of V/P shunt

Case 2:

The patient was a 9 year-old boy applied to our clinic in 2011. He was diagnosed as Neurofibromatosis-1 (NF-1) three years ago.

Cranial and spinal MRIs for routine control showed left C4-5 intradural neurofibroma, and it was doubled in size during 9 months (Fig-8).

He had also congenital cervical kyphosis 20 degree (Fig-9). Neurological examination revealed that left arm abduction was 4/5 in muscle strength. He had huge (10x15 cm) subcutaneous plexiform neurofibroma at the left side anterior cervical area. He underwent operation.

Left C4 hemilaminectomy and C5 sup hemilaminectomy were done. Midline structures and facet joint were kept intact.

Gross total tumor excision was achieved with control cervical MRI showing no residual tumor. Philadelphia type semirigid collar was recommended in order to reduce pain for short period (3-5 days). Early isometric cervical exercises were thought to him, and his mother. At 6th month he came for control. His mother said that he has kept cervical collar 3-4 weeks, he didn't do exercises. His complaint was neck pain.

His neurological examination was intact. His cervical X-ray showed that his cervical kyphosis increased to 68 degree (Fig-10). He underwent intensive physical therapy and rehabilitation program. 3 months later his pain was resolved but the degree of kyphosis didn't change.

His control cervical MRI showed that no residual or recurrent intradural tumor with cord compression at C4 level.

Figure-4. T2 weighted sagittal cervical MRI showing C3-4, C4-5 and C5-6 severe spondylosis with osteophytic supur formation causing foraminal narrowing, and C4-T1 cystic enlargement continued. C4 and C5 total laminectomy and C6 superior hemilaminectomy areas visualized.

The family was informed widely, emphasizing that he has NF-1, and he may have other neurofibromas at the cervical area ever, and he was a child and his spinal column would lengthen. But his kyphosis must have been corrected because it was shown that when the Gore angle was between 21 and 78 degree, the intramedullary pressure was increasing more than 50 mmHg (2). Thus he underwent operation with intraoperative neuromonitoring, C4 corpectomy, insertion of cage and anterior fusion with C3-5 anterior cervical plating, then C3,4,5 lateral mass fusion with screws were performed (Fig-11). Due to the reasons mentioned above the craniocervical instrumentation and fusion were not recommended at this stage. The patient was under follow-up for 2 years without any pain and neurological deficit.

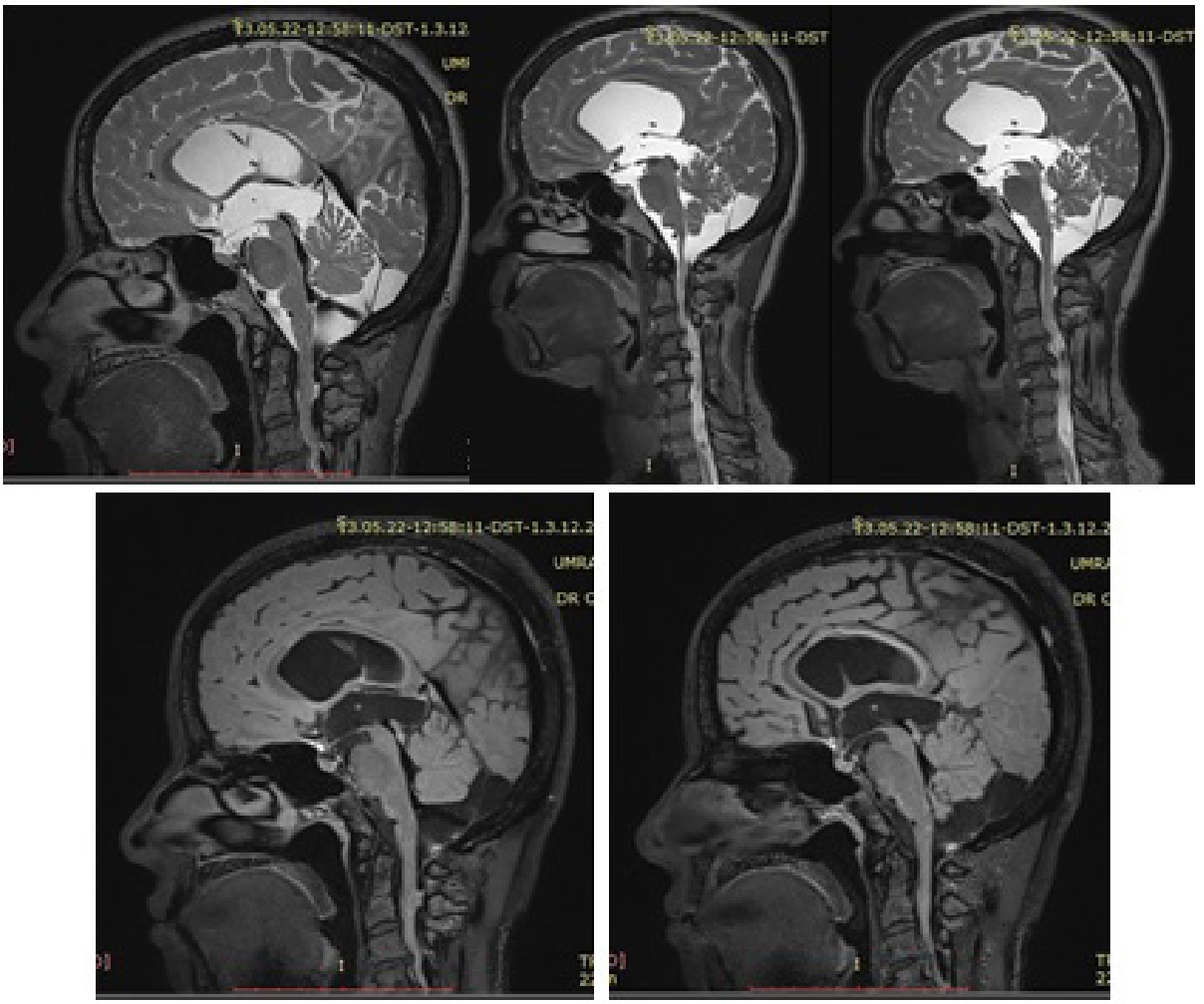

Figure-5. 3D CSF flow MRI was performed and showed CSF flow through the aqueductus Sylvius, Foramen of Magendie, and spinal subarachnoid spaces

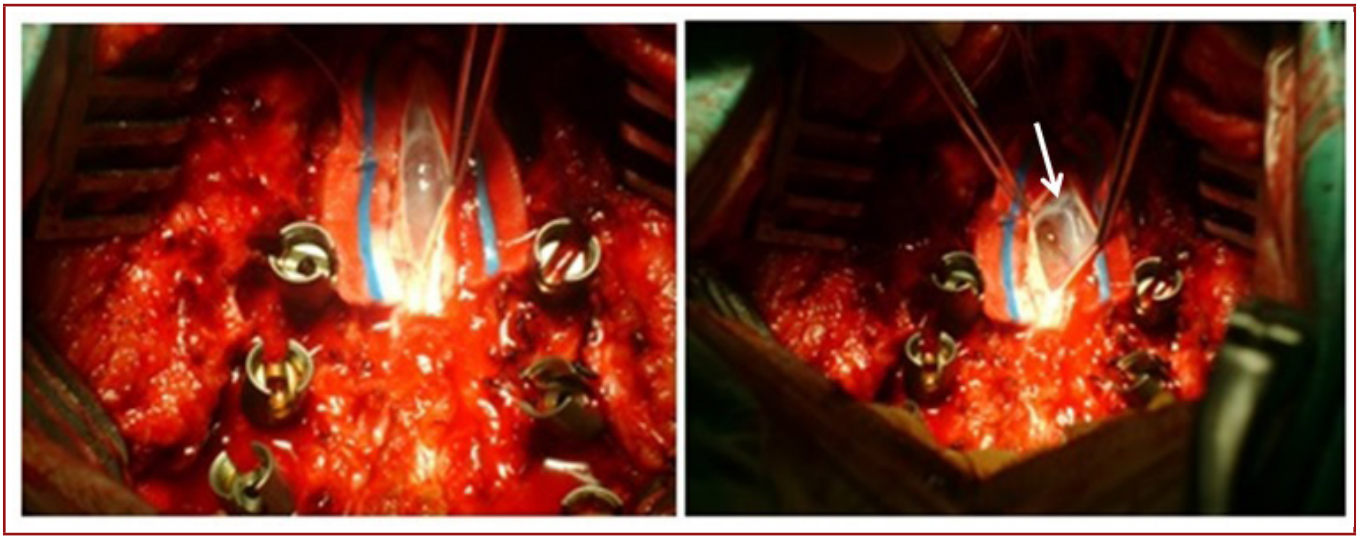

Figure-6. Intraoperative picture showing the thick arachnoid band (arrow) at superior T1 level.

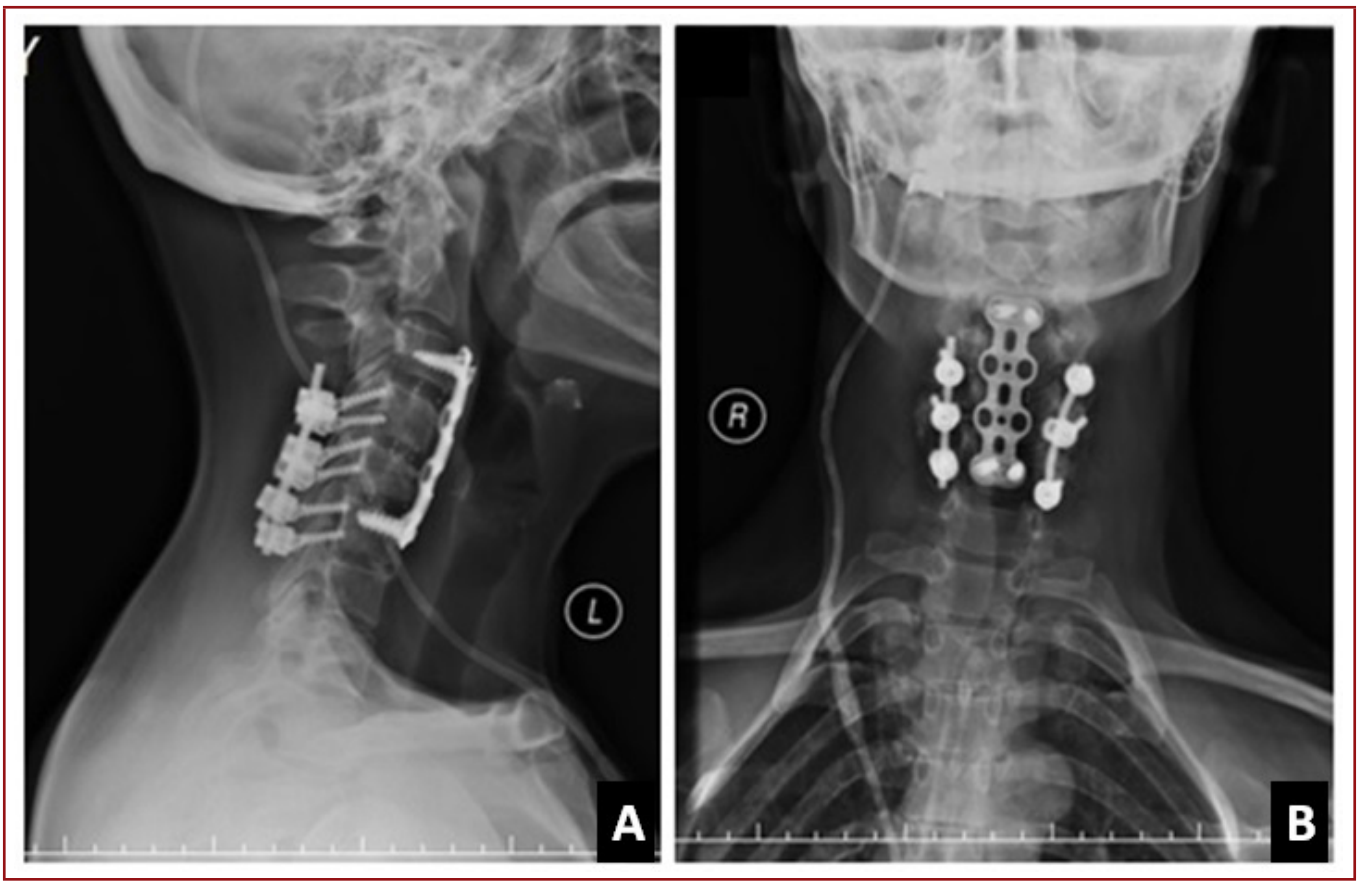

Figure-7. Lateral (A) & PA (B) cervical x-rays showed 360 degree enstrumentation of the cervical area

Case 3:

The patient was a 20 year-old girl applied to our clinic in 2012. She was operated on for tethered cord and scoliosis when she was 11 year-old. Thoracolumbar pedicle screw fixation and bone fusion which was not known if it was allograft bone matrix or synthetic bone graft substitutes were done. After operation her complaints (back and leg pain) did not resolve. 2 years later her instrumentation was removed because of back pain. She has had physical therapy and rehabilitation intermittently ended with increase of back and leg pain, and hypoesthesia. For the last 1 year, her complaints increased especially on the left leg with difficulty in walking. When she walked, she felt pain on her back, and pulling on the left leg with a severe pain on the posterior cervical and occipital area. Her neurological examination was revealed monoparesis and hypoesthesia on the left leg, heavy on the distal part. Cranial and whole spinal MRIs showed that she had no Chiari malformation, but she had scoliosis with vertebrae anomalies (L2 hemivertebrae, L1 butterfly vertebrae) (Fig-12), and tethered cord (Fig-13). She underwent operation, and after paravertebral muscle dissection it was seen that her lumbar area had 3,5 cm-thick, and 7 cm-wide intensive bony fusion (Fig-14). Using high-speed drill the spinal dura was found on the thoracolumbar area. The first dural opening was at the L4-5 level for untethering from the first operation. The dura was opened until S2 level, and it was seen that tethering continued until that level. The cord was released, and dura was closed as watertight fashion. The procedure was ended at this stage because the bony fusion was so intensive and there was no reason trying to crush it for correcting the scoliosis. After operation she underwent intensive physical therapy and rehabilitation. Her numbness and weakness of the left leg resolved significantly. Her back and neck pain ended.

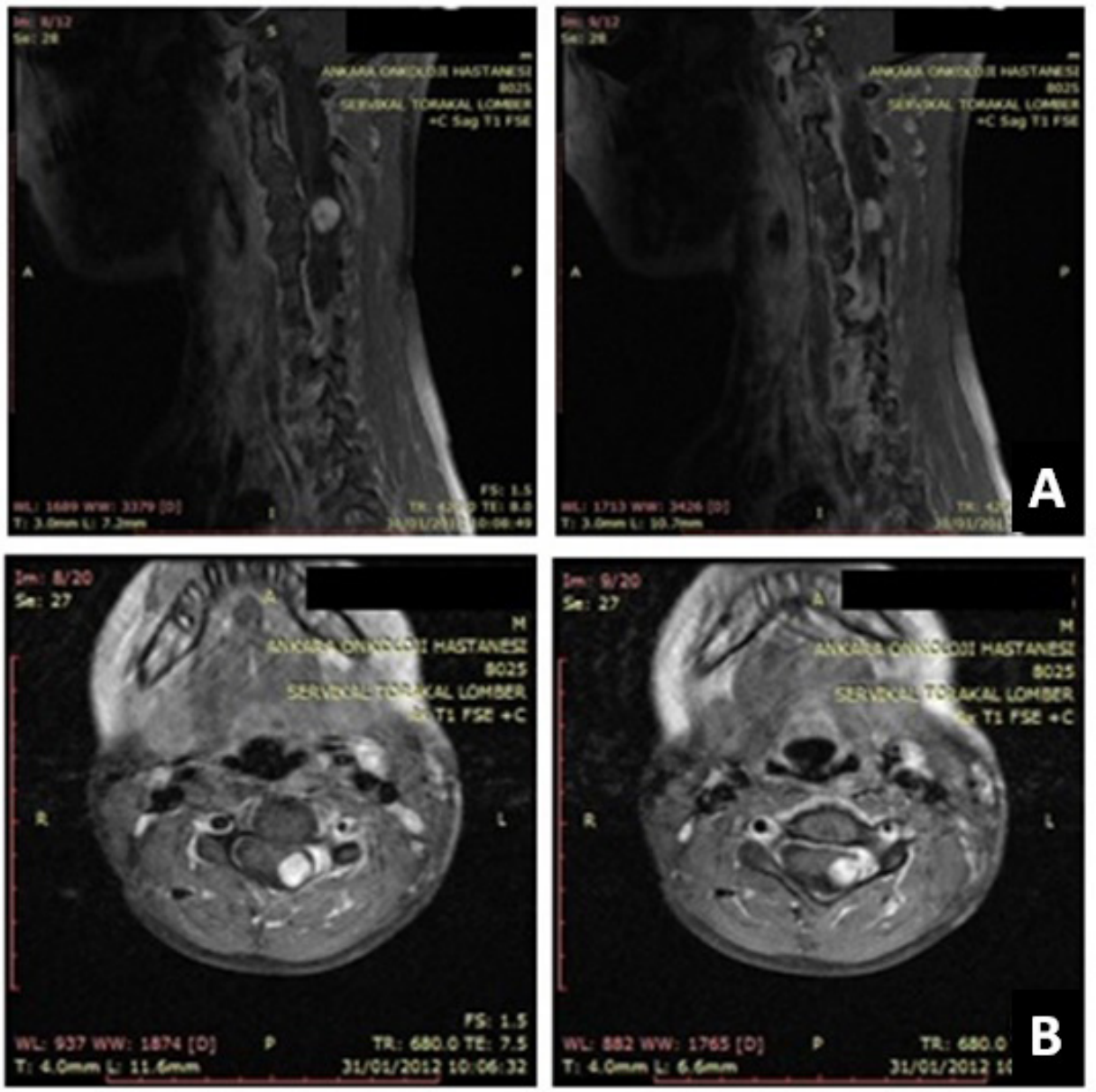

Figure-8. T1 weighted sagittal (A) and axial (B) MR images with contrast showing intradural neurofibroma at C4-5 level, located on the left side.

Figure-9. T2 weighted sagittal cervical MRI showing the pre-operative cervical kyphosis angle measured by posterior tangent method. It was 20 degree.

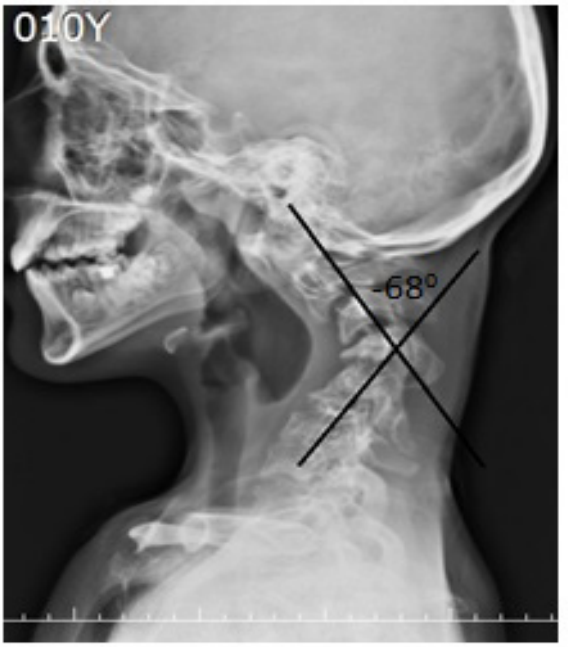

Figure-10. Lateral cervical x-ray showing cervical kyphosis angle measured by posterior tangent method at post-operative 6th month. It was 68 degree.

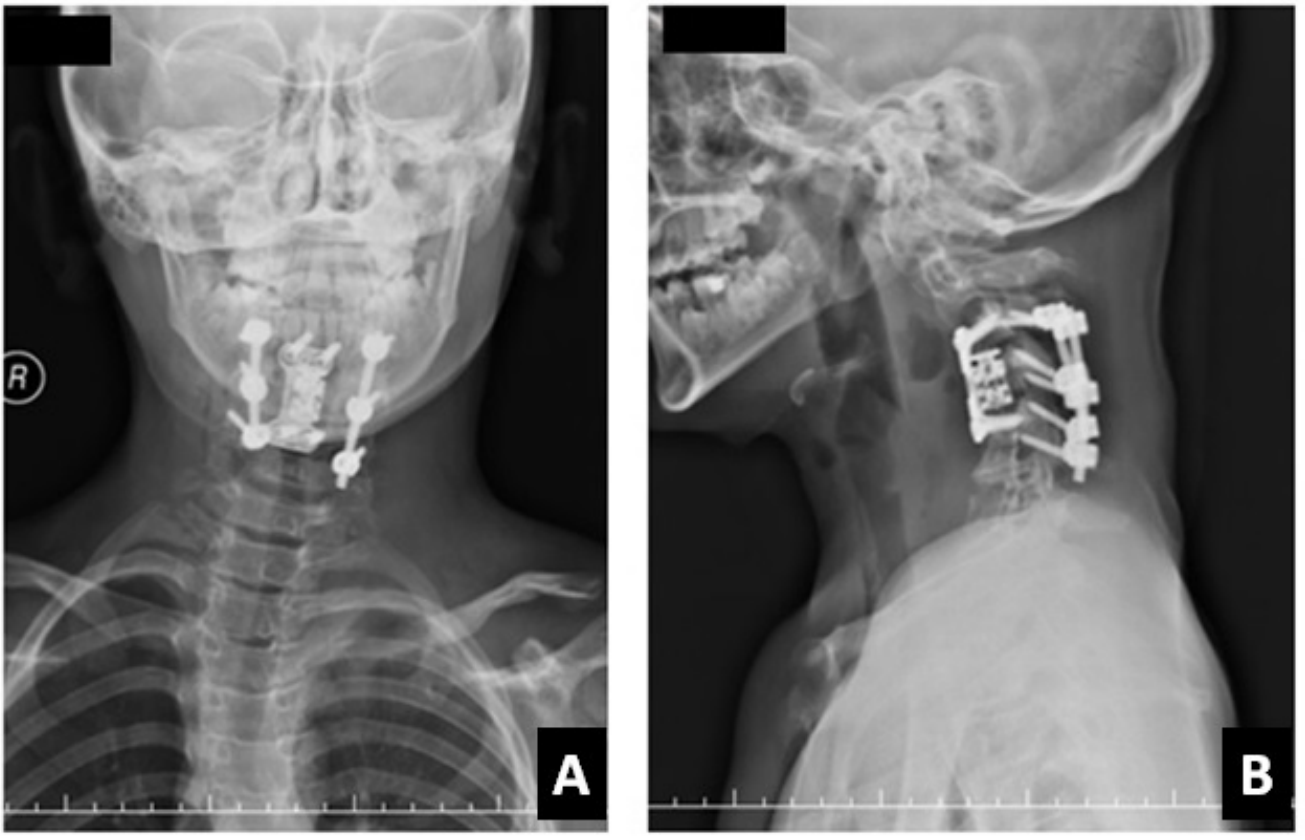

Figure-11. PA **(A)** & Lateral **(B)** cervical x-rays showed 360 degree instrumentation and fusion of the cervical area.

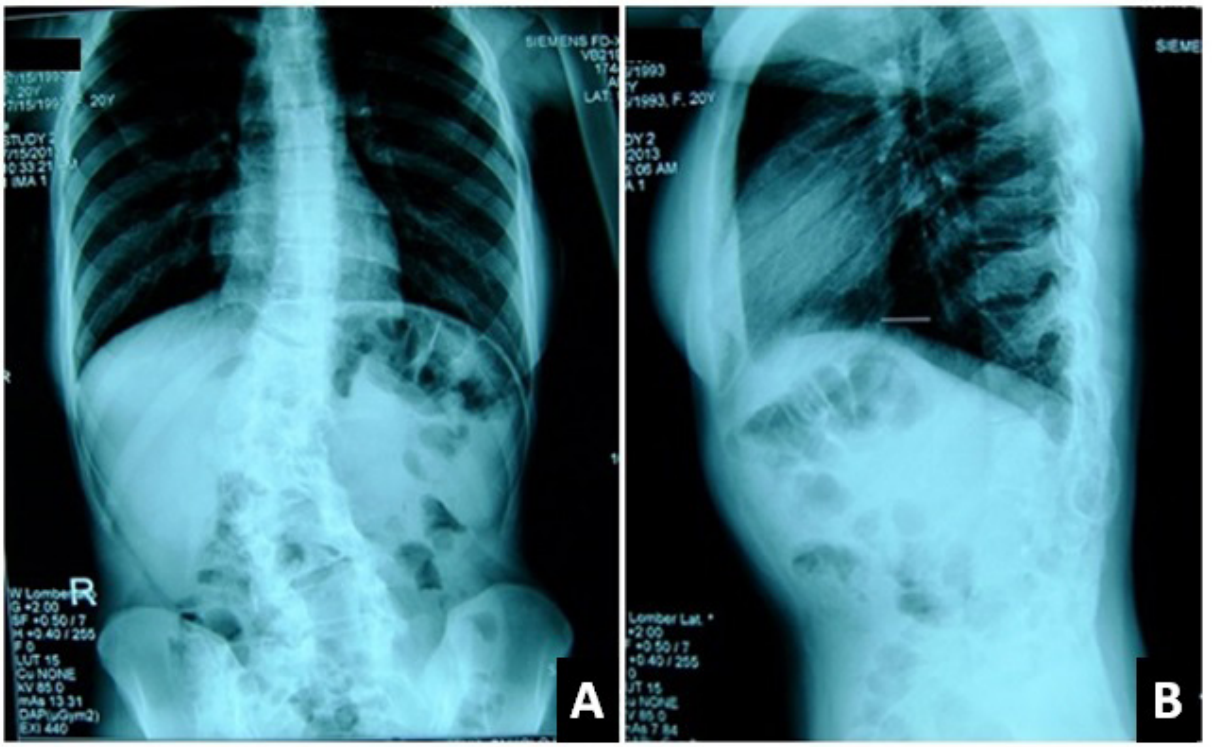

Figure-12. PA **(A)** & Lateral **(B)** cervical x-rays of Case-3 showed scoliosis, and previous L4, L5, S1 laminectomy areas.

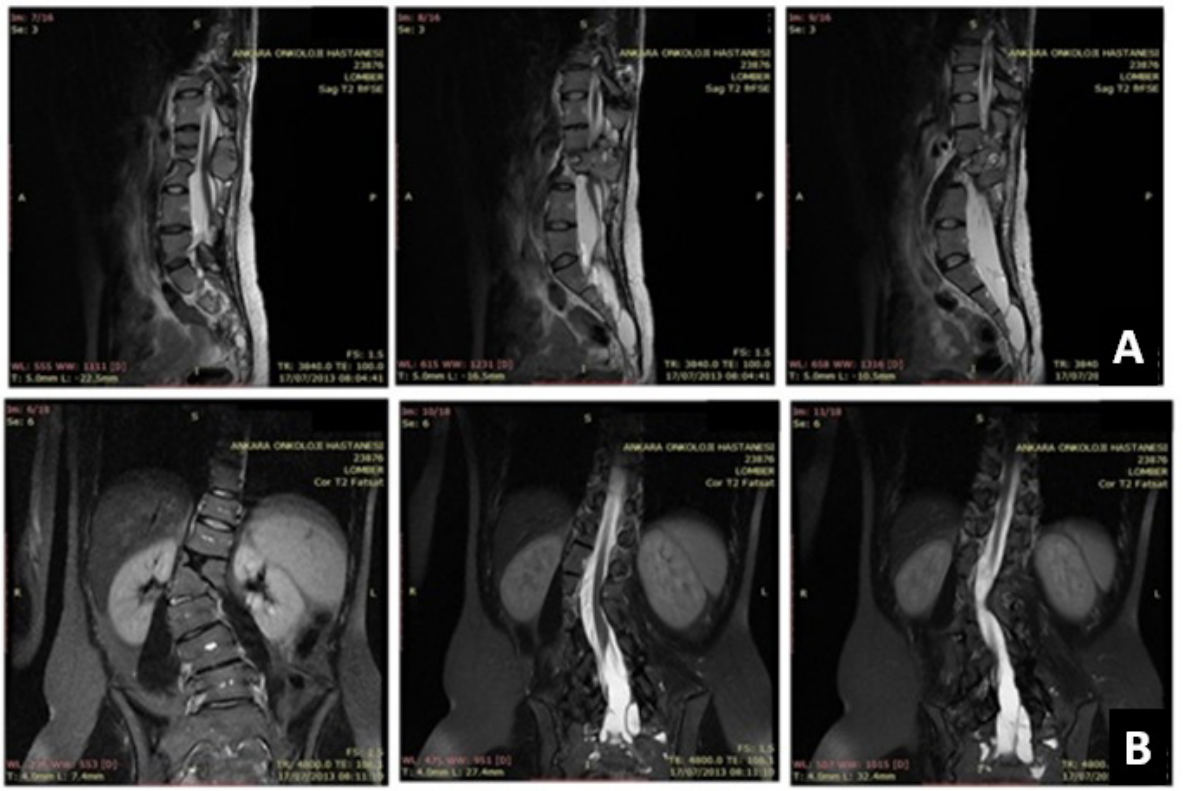

Figure-13. T2 weighted sagittal **(A)** and coronal **(B)** lumbar MR images showing scoliosis with L2 hemivertebrae, L1 butterfly vertebrae, conus ending almost at L5-S1 level with intradural septations resembling tethered cord.

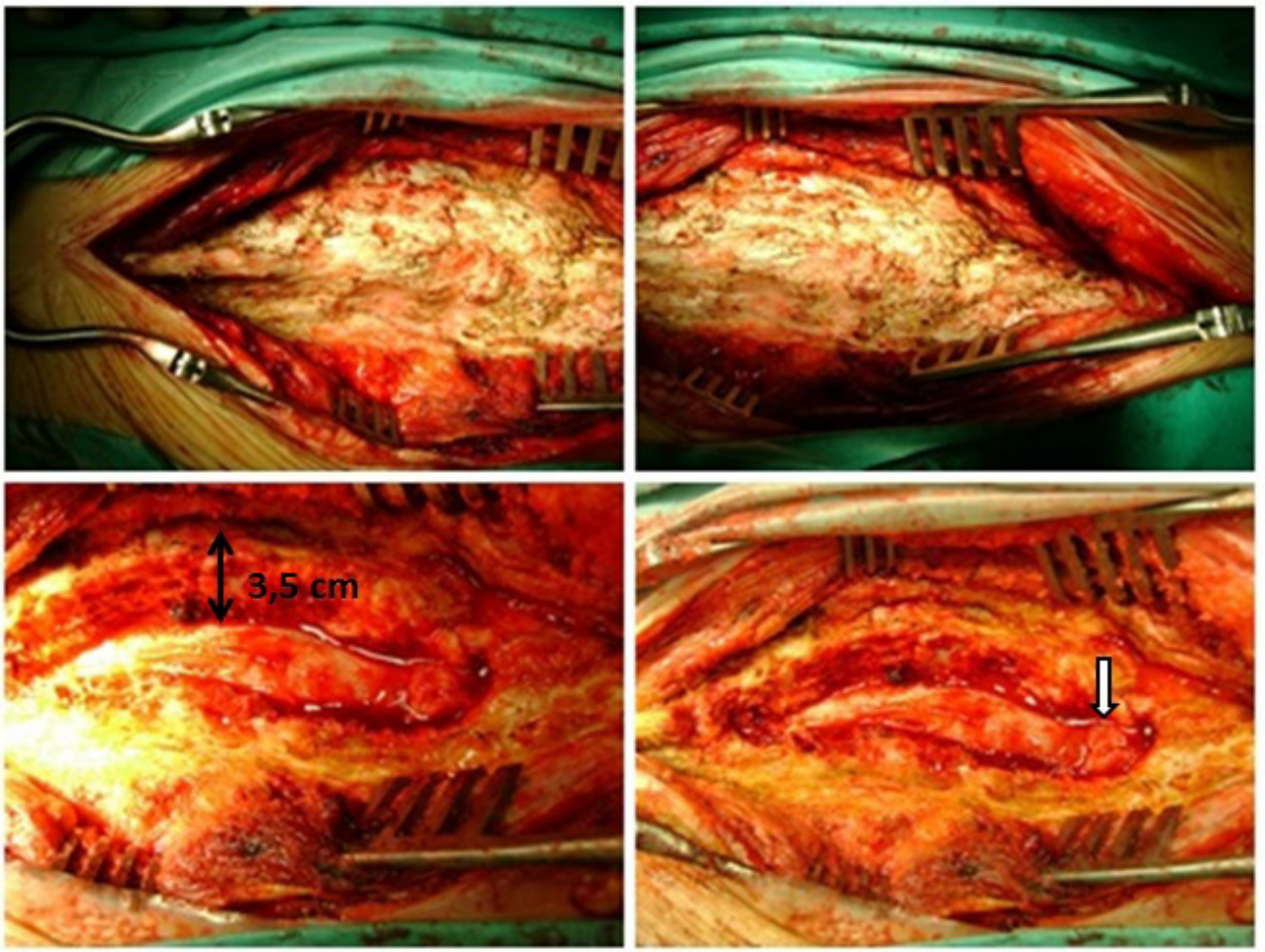

Figure-14. Intraoperative picture of the Case-3 showed 3,5 cm-thick bony fusion (black arrow) of the whole lumbar area, and previous dural opening was at the L4-5 level (white arrow)

Complications

Case-3 had CSF fistula after operation, which was resolved in 3 days with bed rest and dressing the wound.

RESULTS

All patients have some associated childhood neurologic disorders that complicated or prolonged surgery. Patient 1's previous CSF diversion yielded high risk of cerebellar herniation. Removing arachnoiditis needed extra laminectomy and dural opening. Difficulty of case 1's treatment was performing laminectomy with avoiding cerebellar herniation. Neurofibromas of the patient 2 required excision of these lesions. For this case, necessary of intradural and extradural tumor resection made difficult and prolonged the kyphosis correction. For untethering during scoliosis correction of the patient 3's tethered cord craved time consuming extra procedures, neuromonitoring, dural opening and microtechnique. Associated neural pathologies requires additional preoperative evaluation, using extra imaging modalities and excessive surgical planning. At the same time, surgical complication rates are getting higher with every associated disease. Fortunately, we saw only one serious complication after these 3 patient's operations. After untethering of the patient 3's tethered cord, a CSF fistula developed. Fistula closed after a 3-day bed resting and wound care. This is the only serious complication of these three patients. It needed no reoperation for dural repair. These procedures were challenging and time consuming.

DISCUSSION

For the Patient-1, it was difficult to decide from where to start. If the patient was shunt dependent, the cervical laminectomies, and dural opening would have the risk of cerebellar herniation. So it would have been necessary to fix the shunt first. But she may have also had arrested hydrocephalus and posterior cervical decompression, anterior discectomies, and spondylectomies in one session would have been enough for resolving her

complaints. Shunt reservoir tap was performed but it had been not a suitable method to measure the CSF pressure from a 22 year-old shunt, because of the ventricular catheter may have been hemi-obstructed, too. The history of severe headache and vomiting after LP also suggested hydrocephalus but this was not supported by other clinical tests such as ophthalmic evaluation for papilledema. During the first exploration of the cervical cyst, it was thought that arachnoiditis was caused by hemorrhages from V/P shunt insertion 22 years ago as an only possible reason. There is no literature in PubMed related to V/P shunt complication, subdural/epidural hematoma and cervical arachnoiditis and/or arachnoid cysts. So we decided to make staged surgery not to harm, and over treat the patient. At every step, the patient evaluated, examined again and again. So we took the risk and started from the cervical area first. Her shunt is still untouched but under follow-up with ophthalmological and radiological tests. Regular follow-up for such a patient by the same neurosurgical team and early intervention of the cervical cyst may have prevented the compression of the cervical cord and excessive degeneration of the cervical column. V/P shunt dysfunction may have been realized earlier, and the shunt pump may have been changed to programmable one with the replacement of distal and if needed proximal catheters. Ultimately, continuing question mark about the shunt dysfunction may have been extinct.

For Patient-2, previous studies of asymptomatic volunteers have revealed that the greatest variation in regional sagittal neutral upright spinal alignment occurs in the cervical spine with "normal" alignment ranging up to +15 to +20° kyphosis. Minor intramedullary pressure (IMP) increases of 2-5 mmHg were observed when the Gore angle was <+21°. Gore angles ranging from +21° to +78° resulted in statistically significant increases in IMP ranging to >50 mmHg [2].

Cervical kyphosis is relatively common and can develop due to infection, tumors, or surgery; however congenital cervical kyphosis is a rare clinical condition. It is defined as kyphosis induced by an abnormal vertebral body, including congenital failure of formation (type-1), congenital failure of segmentation (type-2), and mixed failure (type-3). Cervical kyphosis may occur with NF1 and is often associated with vertebral dysplasia. Outcomes of cervical spinal fusion in patients with NF1 are not well described because of the rarity of the condition. There are only two references in the literature (3-4). Most of the patients underwent anteroposterior cervical fusion [3-4]. Kawabata et al. [4] suggested dystrophic changes in the vertebrae make surgical correction and fusion of the deformity extremely difficult. The kyphosis angles improved after surgery but the patients had still some degree of kyphosis. The partial dislocation of the distal fibula graft after removing the halo west is the surgical complication. Helenius et al. recommended anteroposterior surgery provided better correction of cervical kyphosis than posterior fusion in children with NF-1. Thirteen patients of 22 patients had complications and nine needed revision surgery [3]. In light of the foregoing findings, cervical kyphosis in NF-1 patients is difficult to treat, may need consecutive operations, and should be followed with close attention.

Patient-3 has congenital scoliosis which is the presence of abnormal coronal plane curvature in spine secondary to a failure of formation, segmentation, or a combination of the two arising from abnormal vertebral development. Congenital scoliosis occurs 1 in 1000 newborns [5-6]. As a developmental anomaly, it is associated with various organ system abnormalities including neural axis. The close relationship of embryonic development of vertebrae and spinal cord causes co-existence of neural and vertebral malformations such as tethering of the cord, diastematomyelia, lipomas, syringomyelia, and lipomeningocele [7-10]. The MRI studies showed the intraspinal anomalies range from 24,5 % to 47 % [10-12]. Hemivertebrae was the most common anomaly. The incidence of intraspinal anomaly in patients with failures of segmentation and mixed defects were significantly higher than patients with failures of formation [9-10,13]. Tethered cord was the most common intraspinal abnormality in congenital scoliosis patients.

The options for conservative management for congenital scoliosis are less effective when compared with idiopathic scoliosis [14]. An MRI examination of the entire spine is recommended before any surgical intervention [15-16]. Neurosurgical evaluation and operation are recommended for any anomaly which tethers the cord before attempting surgical correction of the deformity. Surgical treatment is indicated for deformities that are increasing in severity, or an anomaly that is predicted to have a high risk for progression [17]. In situ fusion and convex hemiepiphysiodesis have been described for congenital scoliosis with minimal deformity over a short section [18]. But both procedures have been reported to have limited success with minimal deformity correction [19], and the development of crankshaft phenomenon [20]. Earlier hemivertebrae excision and short-segment posterior spinal fusion have been advocated to prevent future curve progression of the deformity and/or the development of large compensatory curves [21]. This patient underwent her first operation almost 14 years ago. Untethering of the cord and correction of the spinal deformity were planned in the same session. Untethering of the cord could have not been achieved, so the scoliosis was fixed without correction. When the reason for tethered cord is not a thick/fatty filum terminale, the untethering operation can be long and complicated procedure. For Patient-3, it could have been better just untethering the cord first, and then following the progression of scoliosis. Then, a detailed plan for the second operation could have been prepared for the favorable correction of the scoliosis. But inadequate planning and insistence on going on the operation abolished the chance of any other operation for scoliosis.

Surgical treatment of patients with spinal diseases may become a quite challenging case when they have congenital anomalies or CNS related problems. Expectations of only one surgery that solve all the problems makes surgeon trail to desperation and pessimism. In very first planning, staging surgical approach should be kept in mind for these kinds of patients. Besides, growing of spine and spinal cord at different rates shouldn't be forgotten for children. The whole spinal axis must be kept under lifetime control by some regular intervals for spine patients with additional congenital or CNS anomalies.

That this series were consisted of only three patient and varieties of associated neurological disorders are the main limitation of this study. However, the thing that emphasize in this manuscript, spinal surgeons should be awake for associated neurologic disorders in spinal deformity or degenerative spine cases. These associations are time consuming and needs extra effort. Complication rates are higher than solely spinal surgeries. We need larger series for statistical analysis. Besides, classification of associated neurological disorders is the requirement of this kind of studies. Making any classifications also needs larger patient population.

REFERENCES

1. Algin O, Ucar M, Ozmen E, Borcek AO, Ozisik P, Ocakoglu GE, Tali T. Assessment of third ventriculostomy patency with the 3D-SPACE technique: a preliminary multicenter research study. *J Neurosurg* 2015; 122(6): 1347-1355.
2. Basu PS, Elsebaie H, Noordeen MH. Congenital spinal deformity: a comprehensive assessment at presentation. *Spine (Phila Pa 1976) 2002;* 27:2255-9.
3. Bradford DS, Heihoff KB, Cohen M. Intraspinal abnormalities and congenital spine deformities: a radiographic and MRI study. *J Pediatr Orthop 1991;* 11:36-41.
4. Chang DG, Kim JH, Ha KY, Lee JS, Jang JS, Suk SI. Posterior hemivertebra resection and short segment fusion with pedicle screw fixation for congenital scoliosis in children younger than 10 years: greater than 7-year follow-up. *Spine 2015;* 40: E484–E491.
5. Chavanne A, Pettigrew DB, Holtz JR, DollinN, Kuntz C 4th. Spinal cord intramedullary pressure in cervical kyphotic deformity: a cadaveric study. *Spine* 2011; 36(20): 1619-1626.
6. Giampietro PF, Blank RD, Raggio CL, Merchant S, Jacobsen FS, Faciszewski T, Shukla SK, Greenlee AR, Reynolds C, Schowalter DB. Congenital and idiopathic scoliosis: clinical and genetic aspects. *Clin Med Res 2003*; 1:125-36.
7. Gupta N, S R, G B, Shetty A. Vertebral and Intraspinal Anomalies in Indian Population with Congenital Scoliosis: A Study of 119 Consecutive Patients. *Asian Spine J 2016 Apr;* 10(2):276-81.
8. Helenius IJ, Sponseller PD, Mackenzie W, Odent T, Dormans JP, Asghar J, Rathjen K, Pahys JM, Miyanji F, Hedequist D, Phillips JH. Outcomes of Spinal Fusion for Cervical Kyphosis in Children with Neurofibromatosis. *J Bone Joint Surg* 2016; 98-A (21): e95.
9. Hedequist D, Emans J. Congenital scoliosis. *J Am Acad Orthop Surg 2004;* 12:266–275.
10. Hedequist D, Emans J. Congenital scoliosis: a review and update. *J Pediatr Orthop 2007;* 27:106–116.
11. Kesling KL, Lonstein JE, Denis F, Perra JH, Schwender JD, Transfeldt EE, Winter RB. The crankshaft phenomenon after posterior spinal arthrodesis for congenital scoliosis: a review of 54 patients. *Spine 2003*; 28: 267–271.
12. Kawabata S, Watanabe K, Hosogane N, Ishii K, Nakamura M, Toyama Y, Matsumoto M. Surgical correction of severe cervical kyphosis in patients with neurofibromatosis Type 1. *J Neurosurg Spine 2013*; 18(3): 274-279.
13. Liu YT, Guo LL, Tian Z, Zhu WL, Yu B, Zhang SY, Qiu GX. A retrospective study of congenital scoliosis and associated cardiac and intraspinal abnormities in a Chinese population. *Eur Spine J 2011*; 20:2111-4.
14. McMaster MJ, Ohtsuka K. The natural history of congenital scoliosis: a study of two hundred and fiftyone patients. *J Bone Joint Surg Am 1982*; 64:1128-47.
15. McMaster MJ. Occult intraspinal anomalies and congenital scoliosis. *J Bone Joint Surg Am 1984*; 66:588-601.
16. McMaster MJ, David CV. Hemivertebra as a cause of scoliosis. A study of 104 patients. *J Bone Joint Surg Br 1986;* 68:588–595.
17. Pahys JM, Guille JT. What's New in Congenital Scoliosis? *J Pediatr Orthop. Dec 22, 2016;* doi: 10.1097/BPO.0000000000000922.
18. Shands AR Jr, Bundens WD. Congenital deformities of the spine; an analysis of the roentgenograms of 700 children. *Bull Hosp Joint Dis 1956;* 17:110-33.
19. Shen J, Wang Z, Liu J, Xue X, Qiu G. Abnormalities associated with congenital scoliosis: a retrospective study of 226 Chinese surgical cases. *Spine (Phila Pa 1976) 2013;* 38:814–818.
20. Thompson AG, Marks DS, Sayampanathan SR, Piggott H. Long-term results of combined anterior and posterior convex epiphysiodesis for congenital scoliosis due to hemivertebrae. *Spine 1995;* 20: 1380–1385.
21. Winter RB, Moe JH, Eilers VE. Congenital scoliosis a study of 234 patients treated and untreated. Part I: natural history. *J Bone Joint Surg Am 1968;* 50:1-15.

Volume: 28, Issue: 3, July 2017 pp: 187-190 CASE REPORT

PERCUTANEOUS SACROPLASTY FOR THE TREATMENT OF SACRAL PEDICLE SCREW LOOSENING IN AN OSTEOPOROTIC PATIENT

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ABSTRACT:

Pedicle screw loosening is a major concern especially in the osteoporotic spine. It results from the loss of metal-bone interface integrity. Once a screw pullout occurs, the surgeon should revise the implant. Different salvage techniques exist such as using larger screws, screws with a larger thread depth and pitch, expandable screws, screws with bicortical purchase, milled bone graft impacted into the pilot hole, or PMMA augmented screws. We describe a new, minimally invasive salvage technique that could be an alternative to open revision surgeries. As an alternative to open, major revision surgeries for failed and/or loosened instrumentation systems, we suggest minimally invasive cement augmentation procedure under local anesthesia.

Key words: pedicle screw, sacrum, augmentation, vertebroplasty, polymethlymethacrylate

Level of Evidence: Case report, Level IV

INTRODUCTION

Pedicle screw placement is a well-known and increasingly performed technique used to achieve fixation and fusion in thoracolumbar surgery. Since its first introduction by Harrington and Tullos in 1969 [6], the use of pedicle screw instrumentation has become increasingly popular and effective in the management of spinal disorders [6-7,16]. Despite technical advances, pedicle screw insertion is still associated with complications such as nerve root or spinal cord injury, vascular or visceral injury, cerebrospinal fluid leakage, pedicle fracture, screw breakage, screw pullout and late spinal instability [5,11].

The key determinant of pedicle screw performance is the strength of attachment to the spine, which was shown to be directly related to the quality of bone at the insertion site [6-8]. Chronic diseases such as osteoporosis, diabetes or osteolytic lesions negatively affect bone quality and leads to screw loosening. Once the pedicle screw has loosened, restarted symptoms often overcome by further extensive revision surgeries [2,4].

In this report, the authors describe a unique, minimally invasive method for the treatment of screw loosening that could be an alternative to more extensive revision surgeries.

CASE REPORT

71-year-old female patient was admitted to our department with the chief complaint of severe low back pain radiating to her left hip and posterior aspect of left thigh for 2 months. She described increasing pain while sitting and standing. Sacroiliac region was painful on examination. She had a history of previous lumbar disk and instrumentation surgeries. At the last surgery, loosened L5 screws had been removed and PMMA augmentation had been performed. Larger diameter screw had been replaced on the right L5 pedicle, however left L5 screw had not been replaced successfully. So, the construct on the left side had been extended to the sacrum. She was under medication for diabetes mellitus, coronary heart disease and osteoporosis.

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X-Ray images showed asymmetric thoracolumbosacral instrumentation with anterior fusion and PMMA augmentation. Radiolucent halo was observed both around the left S1 and right L5 pedicle screws (Figure-1).

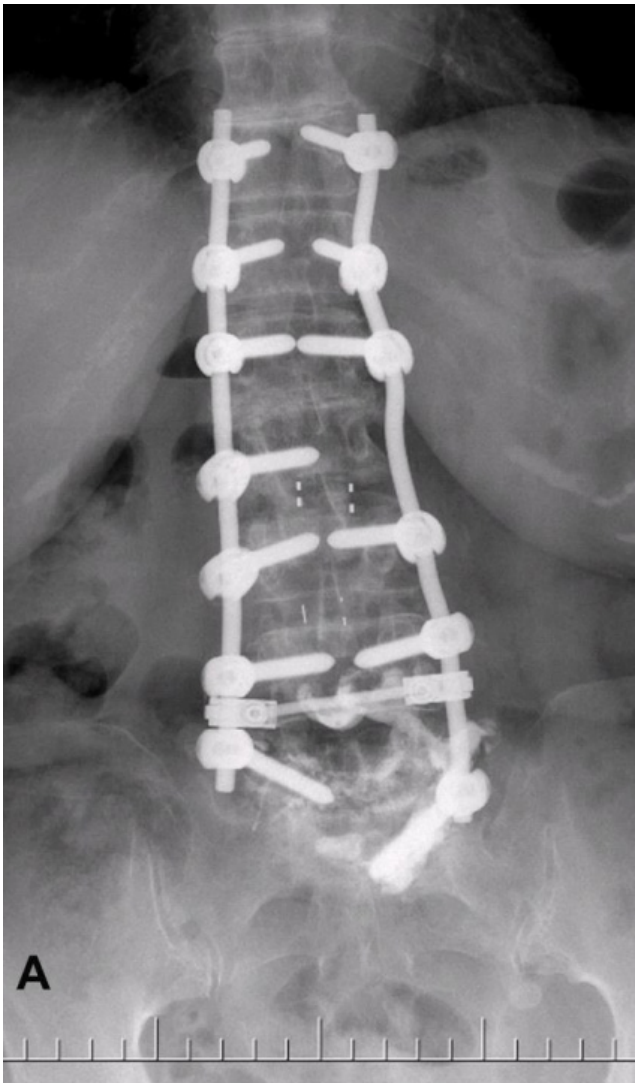

Figure-1. AP X-Ray images showing asymmetric thoracolumbosacral instrumentation with anterior interbody fusion and PMMA augmentation.

According to the patient's symptoms, we decided to revise the S1 screw and to lengthen the implant to the iliac wings. But cardiology and anesthesiology departments indicated high risk for the induction of general anesthesia. In that situation, we thought to augment the loosened sacral pedicle screw with polymethylmethacrylate (PMMA) under local anesthesia.

The patient was operated on the prone position. After the injection of local anesthesia, Jemshdy needle and then working cannula was placed under the guidance of floroscopy. After the confirmation of proper placement of working cannula, PMMA was injected slowly. Approximately 7,5 cc cement was administered to the radiolucent zone around the S1 screw. Procedure was ceased immediately when the cement leakage occured.

Patient was mobilised on the postoperative fourth hour and she did not experience any low back pain. Control X-Rays revealed total obliteration of the radiolucency around the screw with PMMA (Figure-2).

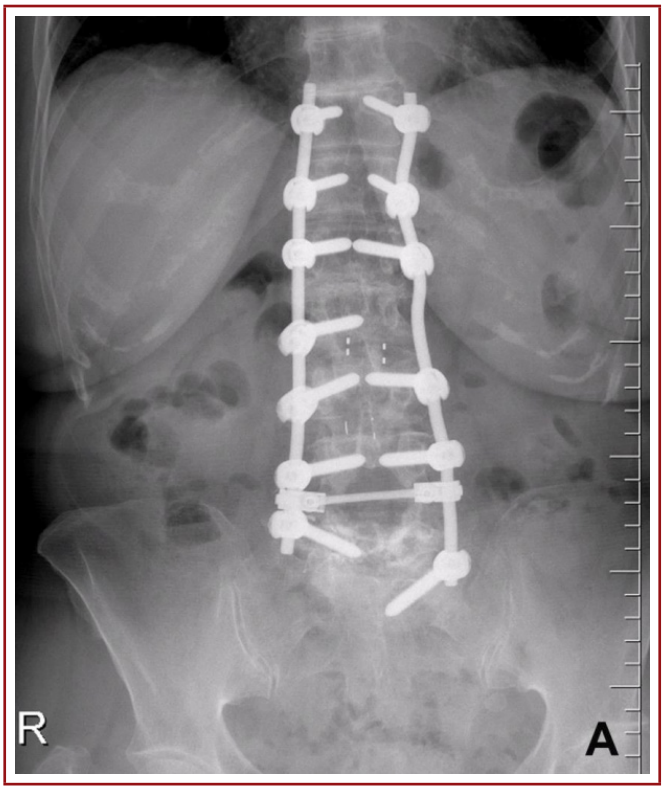

Figure-2. AP postoperative X-Ray images showing total obliteration of the radiolucency around the sacral screw with PMMA.

DISCUSSION

Pedicle screw loosening is a major concern especially in the osteoporotic spine [2,4-5,11-12]. A recent review by Gautschi et al [5] reported screw loosening on 38 cases of 585 cases. It results from the loss of metal-bone interface integrity [2,4,12]. Poor bone density (osteoporosis), excessive strain on the implant, residual sagittal imbalance, screw hole preparation technique, torque of insertion, screw purchase, and direction of screw placement may influence the pullout strength of pedicle screws [9].

Radiolucent 'halo' around the screw is a definite sign of loosening of the screw [12]. This halo is seen as a result of the fibrous tissue surrounding the screws that were formed secondary to excessive movement of screws in bone [12]. Once a screw pullout

or loosening occurs, the surgeon should revise the implant [2]. Different salvage techniques occur such as using larger or expandable screws, screws with bicortical purchase, milled bone graft impacted into the pilot hole, or PMMA-augmented screws [2,4,9,14].

PMMA is commonly used in vertebral augmentation procedures [13-14]. It is typically used to interdigitate with surrounding trabecular bone to increase fixation strength and firmly anchor the screw [8]. Studies showed that cement augmentation with pedicle screw fixation, can increase pedicle screw strength and prevent pedicle screw loosening [2,4,9]. However, PMMA augmentation has also some serious complications such as leakage, thermal and chemical injury [1,4,13].

Calciumphosphate/calcium triglyceride cements could be alternative to PMMA. But they perform weaker constructs than PMMA cements [14]. Sacral screws are prone to loose easily especially in osteoporotic, long segment instrumented and inadequate anterior column supported patients [2-3,15]. In a biomechanical study of long segment 86 fusion model, Fleischer et al [3] found that anterior interbody fusion is very important and significantly reduces the strain on S1 screws similar as iliac screws.

Percutaneous vertebroplasty (PVP) is a minimally invasive procedure that involves radiographic-guided injection of various types of bone cement directly into the vertebral body [13-14]. PVP has gained extensive popularity for the treatment of painful vertebral lesions including metastatic disease and osteoporotic fractures [13]. In our case, unicortical S1 screw was loosened since long segment instrumentation was not balanced adequately with anterior support and/or iliac wings were not involved to the construct. We performed PVP to the radiolucent zone around S1 screw under local anesthesia. We injected PMMA until the radiolucent zone was filled completely. Some cement leakage occured without any symptoms. Our case is unique since PVP under local anesthesia was performed first time in the literature for treating screw loosening.

CONCLUSION

In the treatment algorithm of loosened sacral screws, percutaneous sacroplasty should be kept in mind before extensive major revision surgeries were performed.

REFERENCES

1. Akinola B, Lutchman L, Barker P, et al. Pulmonary cement embolism during cement augmentation of pedicle screw fixation: a case report. *J Orthop Surg (Hong Kong)* 2010; 18(3): 364–366.
2. Aydogan M, Ozturk C, Karatoprak O, Tezer M, Aksu N, Hamzaoglu A. The pedicle screw fixation with vertebroplasti augmentation in the surgical treatment of the severe osteoporotic spines. *J Spinal Disord Tech* 2009; 6: 444–447.
3. Fleischer GD, Kim YJ, Ferrara LA, et al. Biomechanical analysis of sacral screw strain and range of motion in long posterior spinal fixation constructs: effects of lumbosacral fixation strategies in reducing sacral screw strains. *Spine* 2011. [Epub ahead of print].
4. Frankel BM, Jones T, Wang C. Segmental polymethylmethacrylate-augmented pedicle screw fixation in patients with bone softening caused by osteoporosis and metastatic tumor involvement: a clinical evaluation. *Neurosurgery* 2007; 61: 531–537; discussion: 537–538.
5. Gautschi OP, Schatlo B, Schaller K, Tessitore E. Clinically relevant complications related to pedicle screw placement in thoracolumbar surgery and their management: a literature review of 35,630 pedicle screws. *Neurosurg Focus* 2011; 31(4): E8.
6. Harrington PR, Tullos HS. Reduction of severe spondylolisthesis in children. *South Med J* 1969; 62: 1–7.
7. Hirabayashi S, Kumano K, Kuroki T. Cotrel-Dubousset pedicle screw system for various spinal disorders. Merits and problems. *Spine* 1991; 16: 1298–1304.
8. Hu MH, Wu HT, Chang MC, Yu W-K, Wang S-T, Liu C-L. Polymethylmethacrylate augmentation of the pedicle screw: the cement distribution in the vertebral body. *Eur Spine J* 2011; 20(8): 1281–1288.
9. Kang SH, Kim KT, Park SW, Kim YB. A case of pedicle screw loosening treated by modified transpedicular screw augmentation with polymethylmethacrylate. *J Korean Neurosurg Soc* 2011; 49(1): 75–78.
10. McLachlin SD, Al Saleh K, Gurr KR, et al. Comparative assessment of sacral screw loosening augmented with PMMA versus a calcium triglyceride bone cement. *Spine* 2011; 36(11): E699–704.
11. Pihlajamaki H, Myllynen P, Böstman O. Complications of transpedicular lumbosacral fixation for non-traumatic disorders. *J Bone Joint Surg* 1997; 79-B: 183–189.
12. Sanden B, Olerud C, Petren-Mallmin M, Johansson C, Larsson S. The significance of radiolucent zones surrounding pedicle screws: definition of screw loosening in spinal instrumentation. *J Bone Joint Surg* 2004; 86: 457–463.
13. Sonmez E, Yilmaz C, Caner H. Development of lumbar disc herniation following percutaneous vertebroplasty. *Spine* 2010; 35(3): E93–75.

14. Yilmaz C, Atalay B, Caner H, Altinors N. Augmentation of a loosened sacral pedicle screw with percutaneous polymethylmethacrylate injection. *J Spinal Disord Tech* 2006; 19(5): 373–375.

15. Yu BS, Zhuang XM, Zheng ZM, et al. Biomechanical comparison of 4 fixation techniques of sacral pedicle screw in osteoporotic condition. *J Spinal Disord Tech* 2010; 23:404–409.

16. Yuan HA, Garfin SR, Dickman CA, Mardjetko SM. A historical cohort study of pedicle screw fixation in thoracic, lumbar, and sacral spinal fusions. *Spine* 1994; 19: S2279–S2296.

Volume: 28, Issue: 3, July 2017 pp: 191-194 CASE REPORT / OLGU SUNUMU

TETRAPLEGIA AFTER TRAUMA BECAUSE OF OSSIFICATION OF POSTERIOR LONGITUDINAL LIGAMENT

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SUMMARY:

Ossification of the posterior longitudinal ligament (OPLL) is the new bone development and thickening of the posterior longitudinal ligament within the spinal canal. The clinical symptoms of OPLL appear mostly after 40 years of age. Patients complain of pain in the neck and the occipital area, and this is followed by paresthesia and weakness in the upper and lower extremities. We report a case with sudden tetraplegia after trauma because of cervical OPLL.

Key words: Ossification of the posterior longitudinal ligament, Tetraplegia, Cervical trauma

Level of evidence: Case report, Level IV

INTRODUCTION

Ossification of the posterior longitudinal ligament (OPLL) is the new bone development and thickening of the posterior longitudinal ligament within the spinal canal. When OPLL compress the spinal cord or nerve roots neurological deficits, motion problems and voiding difficulties could be seen. We report a patient with OPLL in the cervical spine who developed an almost complete tetraplegia after traffic accident.

CASE REPORT

A fifty-five year old male patient apply to emergency service after trauma with sudden tetraplegia. Neurological deficit recovered in hours. Only distal upper extremities muscle strength was 3/5. Radiological diagnostic test made with computed tomography and magnetic resonance imaging (Figure-1,2,3). Ossification of posterior longitudinal ligament (OPLL) was reported on diagnostic images. Surgery suggested for OPLL. Surgery was performed with $C_{3\text{-}4\text{-}5\text{-}6}$ total laminectomy and lateral mass instrumentation (Figure-4,5,6,7). Postoperatively upper extremities muscle strength was 1/5. MRI performed and spinal cord contusion reported. After 1 week of follow up, muscle strength recovered to 5/5 and patient referred to physiotherapy.

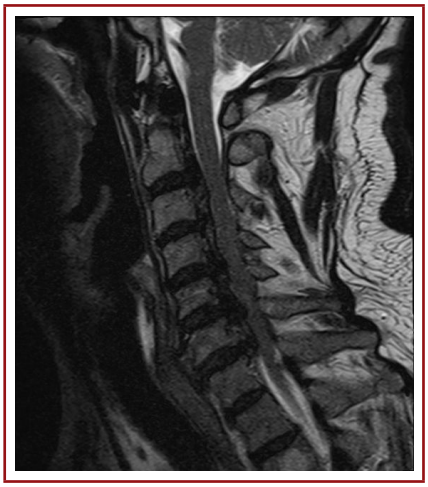

Figure-1. Preoperative MRI sagittal T2 image

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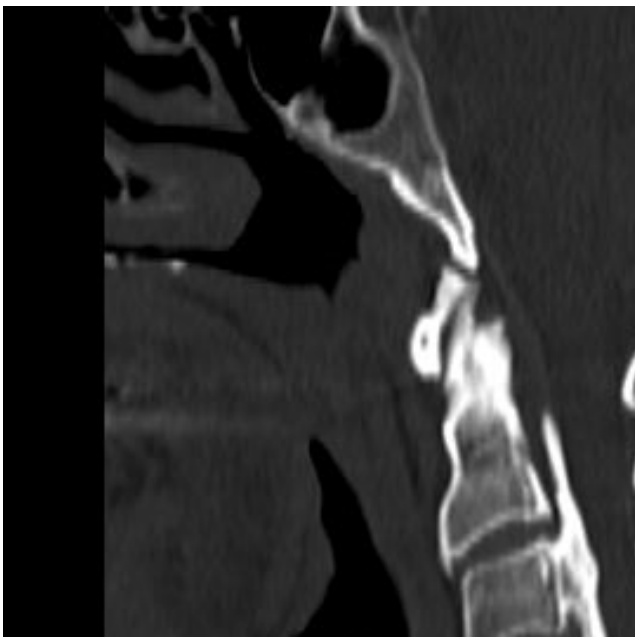

Figure-2. Preoperative CT sagittal image

Figure-3. Preoperative sagittal CT axial image

Figure-4. Postoperative MRI sagittal image

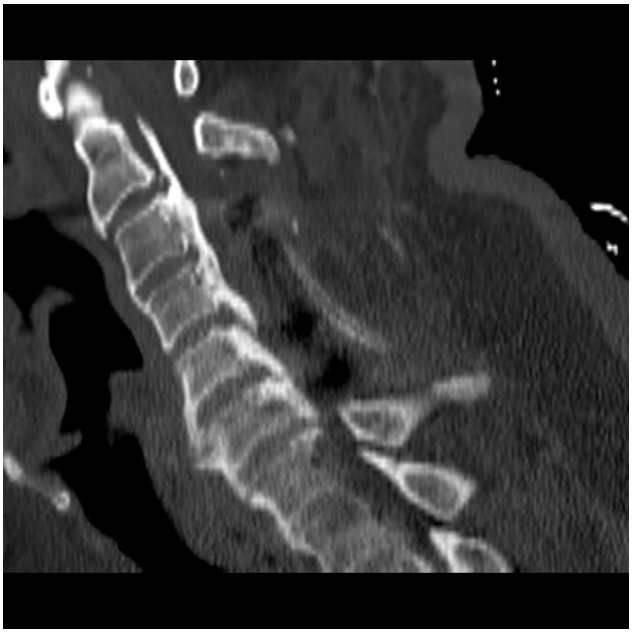

Figure-5. Postoperative CT sagittal image

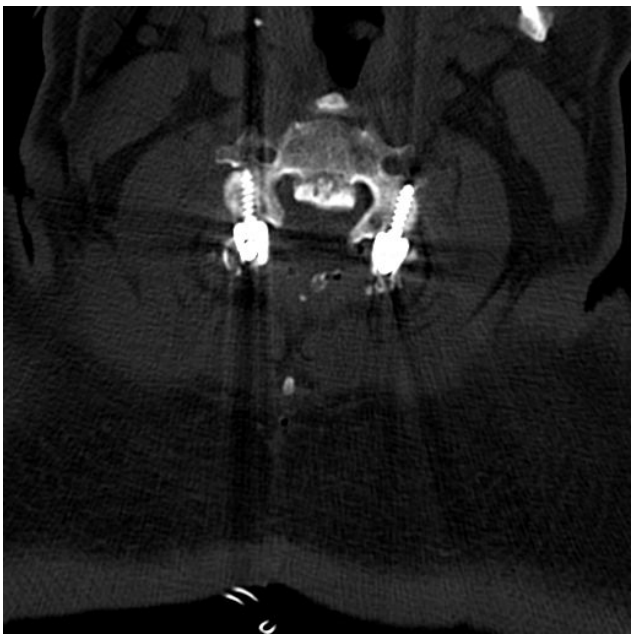

Figure-6. Postoperative CT axial image

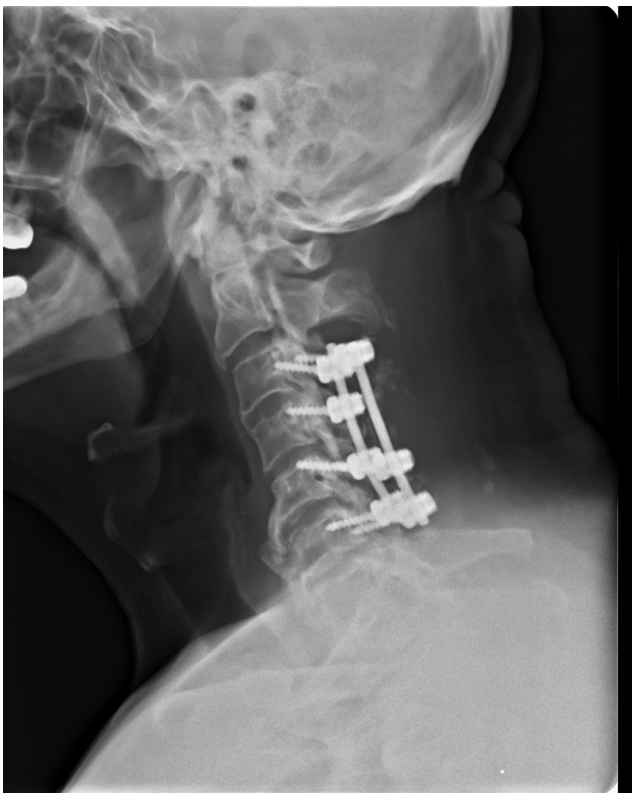

Figure-7. Postoperative cervical vertebral X-ray

DISCUSSION

The clinical symptoms of OPLL appear mostly after 40 years of age. Patients complain of pain in the neck and the occipital area, and this is followed by paresthesia and weakness in the upper and lower extremities. Paresthesia is the most common clinical symptom with a 70% ratio of patients [(1)]. OPLL patients can live without serious problems till spinal canal compression become symptomatic. Conservative treatment could be suggested for patients with mild paresthesia and no evidence of muscle weakness [(5)].

Surgical treatment is generally indicated when symptoms progress in spite of conservative treatment or when there is obvious compression of the spinal cord with neurological deficit. Laminectomy and lateral mass stabilization is considered the best method for treating OPLL involving more than 3 segments. Patients over 65 years of age with serious clinical symptoms for more than 2 years are generally known to have a bad post-operative prognosis because of spinal stenosis [(4)]. As an increase of OPLL has been observed in 89% of cases after laminectomy, and in 34% after cervical canal laminoplasty [(3)].

Complications for simple laminectomy and stabilization could be exampled as infection, stabilization failure, post-operative scar formation in the extra-dural space, post-operative spinal instability and an abnormal post-operative curvature [(6)]. In some reports, traction of a cervical nerve root by a backward shift of the compressed cord followed by injuries to the radicular artery have been noted after operation [(6)].

We report a case with sudden tetraplegia after trauma because of cervical OPLL. Spitzer also reported a similar case after a minor hyperextension injury [(7)]. Cruzeiro et al and Cho et al also reported similar cases that occured spontaneously without any trauma [(1-2)]. OPLL must be followed up because serious results could be seen spontaneously or after traumatic injury.

REFERENCES

1. Cho JL, Park YS, Kim YH. Tetraparesis associated with ossification of the posterior longitudinal ligament of the cervical spine. *Int Orthop (SICOT)* 1999; 23: 247-248.
2. Cruzeiro MM, Vale TC, Pires LA, Franco GM, Pennisi MF. Tetraparesis secondary to cervical ossification of the posterior longitudinal ligamnent. *Arq Neuropsiquiatr* 2007; 65(2-B): 532-535.
3. Hirabayashi K, Satomi K. Operative procedure and results of expansive open-door laminoplasty. *Spine* 1988; 13: 870–876.
4. Hukuda S, Mochizuki T, Ogata M, Schichik K, Shimomura Y. Operation for cervical spondylotic myelopathy. *J Bone Joint Surg* 1985; 67-B: 609–615.

5. Nakanishi T, Mannen T, Tokoyura Y. Asymptomatic ossification of the posterior longitudinal ligament of the cervical spine: incidence and roentgenographic findings. *J Neurol Sci* 1973; 19: 375–381.

6. Rozario RA, Levine H, Stein BM (1978) Cervical myelopathy and radiculopathy secondary to ossification of the posterior longitudinal ligament. *Surg Neurol* 1978; 10: 17–20.

7. Spitzer D. Complications corner: Quadriplegia after a minor hyperextension injury with severe OPLL teaching case and illustrative images. *Surg Neurol Int* 2014; 5: 65-67.

Volume: 28, Issue: 3, July 2017 pp: 195-204 REVIEW ARTICLE

CONGENITAL CHEST WALL DEFORMITIES

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SUMMARY:

Congenital chest wall deformities inhibit patients due to esthetically unpleasant appearance even in the absence of functional cardiac or pulmonary deficit. In most cases the need for correction is based on evident social adaptive difficulties and impairment of worth living sense.

Thoracic scoliosis is seen either with congenital chest wall deformities de novo, or after costal cartilage harvesting, minimal invasive or open correction of chest wall deformities. Anterior chest wall deformities can be put under 5 main categories: Pectus Excavatum, Pectus Carinatum, Poland Syndrome, sternal defects, thoracic deformities seen in diffuse skeletal disorders.

Conservative treatment methods such as using corset are manipulated for starting treatment in childhood and specifically in pectus carinatums. Nuss technique or modifications that are in invasive (Ravitch chondroplasty) or minimal invasive techniques are carried out on elderly people and under the circumstances when conservative methods are unsuccessful. Also vacuum waist technique is one of the treatment methods used in selected cases or for the treatment of the people who do not accept the operation.

In this collection; clinical findings of congenital chest deformities, its classification, embryology, pathophysiology and diagnostic techniques that are mainly used are stated. Also, in company with changing literature; operation indications and traditional surgical correction treatment methods with less invasive new methods are reviewed.

Keywords: Anterior chest Wall deformity, Orthoses, Ravitch chondroplasty, Nuss method.

Level of Evidence: Level V, Review Article

INTRODUCTION

Congenital chest wall deformities can be seen with various anomalies of musculoskeletal system or in a way that it affected isolated costa, cartilage, sternum in various forms. In most of these deformities, there are not certain functional defects in intrathoracic organs and cardiopulmonary and gastrointestinal pathologies that are life-threatening can rarely accompany with it. In almost 6 % of the cases; Marfan Syndrome, Ehlers Danlos Syndrome, connective tissue diseases such as osteogenesis imperfecta and homocystinuria, congenital heart diseases, Down syndrome, scoliosis with the percentage of 26-30% are seen as accompanying diseases [18-25]. To stage the congenital chest deformities, there is not any classification that is accepted as universal [21]. Those diseases, especially the patints of Marfan Syndrome, and Ehlers Danlos Syndrome have got scoliosis, thoracolumar kyphosis and the other spinal deformities [21]. In the Down Syndrome, atlaantoaksial instability is frequently accompanied.

Classically, anterior chest wall deformities can be put under 5 main topics [22]:

1. Pectus Excavatum
2. Pectus Carinatum
3. Poland Syndrome
4. Sternal Defects
5. Thoracic deformities in diffuse skeletal disorders;

The deformity ends up with asphyxiating thoracic dystrophy (Jeune Syndrome), spondylothoracic dysplasia (Jarcho-Levin syndrome), cerebrocostomandibulary syndrome

along with congenital chest wall deformities and they are deformities that can accompany with different degrees of costa aplesia or hypoplasia [17].

PECTUS EXCAVATUS

It can also be named as "Funnel chest" and "trichterbrust", "koilosternia", "chone-chondrosternon".

Generally sternum's lower half or two thirds of it get effected. The most distinct area of the deformity is generally at a little above of xiphoid-sternum mergence level. **(Figure-1).** It is mostly defined 86% at birth or in the first year of life. It almost occurs 2-4 times more in boys than girls. It is the most observed anterior chest deformity with the rate of 1/1000 [17,21].

In literature, it is stated that the very first surgical correction intervention attempt was made by Meyers (1911) and Sauerbruch (1913) [21]. While etiology remains not fully known, it is accepted that the overgrowth of cartilage costa due to the pathogenesis is the key fact of the formation of pectus deformities. Also, it is stated that 37 % of patients with genetic factors have family history [17]. 15% of them have scoliosis and 11 % of these patients have a scoliosis history in their families. The incidence of congenital heart disease is 1.5 % [17]. Patients with Marfan and Prune-Belly syndrome have the incidence of pectus excavatum a lot [27].

Kuhn et al. categorized excavatum types of deformity into 4 in terms of their morphological appearance [17].

a. Cup shaped (localized deep depression)
b. Saucer shaped (diffuse superficial depression)
c. Grand canyon (depression that is in the form of asymmetrical long pipe)
d. Currarino-Silverman Deformity (pouter pigeon deformity, mixed carinatum / excavatum horns of steer)

For typing and rating pectus excavatum deformity, Welch (1980), Oelsnitz (1981), Hümmer (1984), and Haller (1987) published their studies. One of these authors, Welch, described the rating called "Welch index" by estimating the distance between T3 and T9 vertebra corpus and sternum. Today, Haller index is the most used one.

Surgical Indications:

If a case have two or more criterions below, surgical correction is suggested;

1) Pectus excavatum that is progressive or has presence of symptom

2) Restrictive lung disease existence that is measured with pulmonary function tests

3) Cardiac pressure, pulmonary atelectasis and Haller BT index that is >3.25 **(Figure-2)**

4) Cardiac malformations (mitral valve prolapsus or the existence of arrhythmia)

5) Nuss pectus excavatum deformity that occurs after an inadequate correction operation.

In many patients, primary indication occurs due to cosmetic and psychosocial reasons. The views of family, child and the environment towards the deformity should be evaluated well. It must be taken into consideration that the deterioration will increase at later ages.

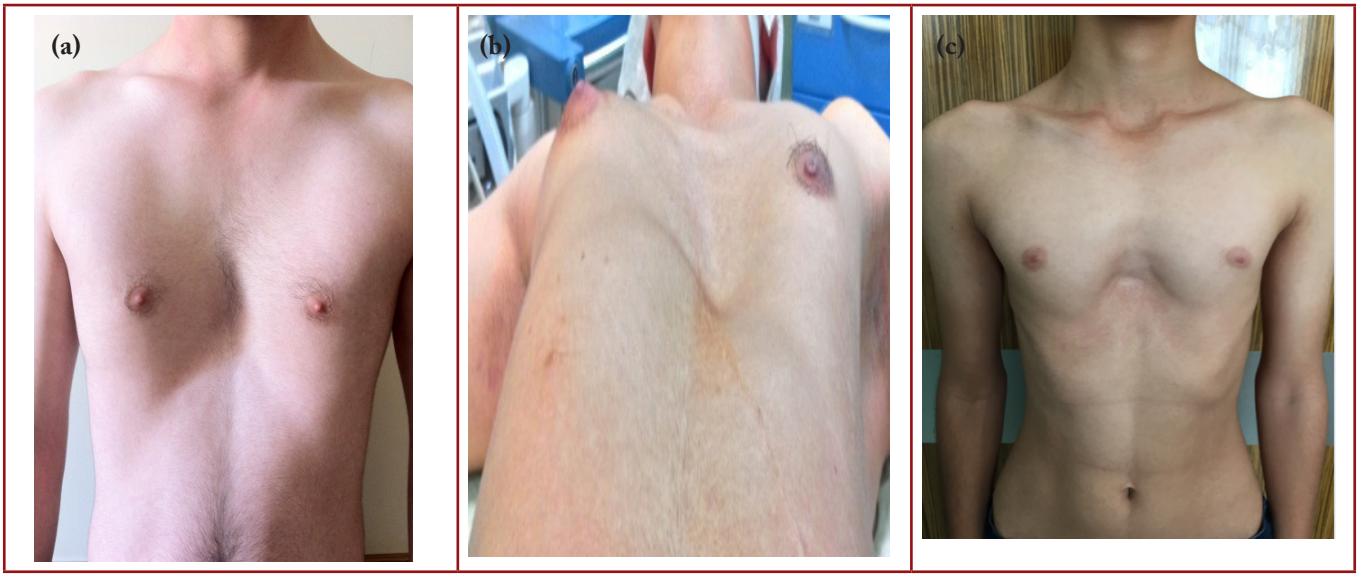

Figure-1.-a,b,c Three cases with difeerent degrees of pectus excavatum deformity (Courtesy of Levent Cansever, MD)

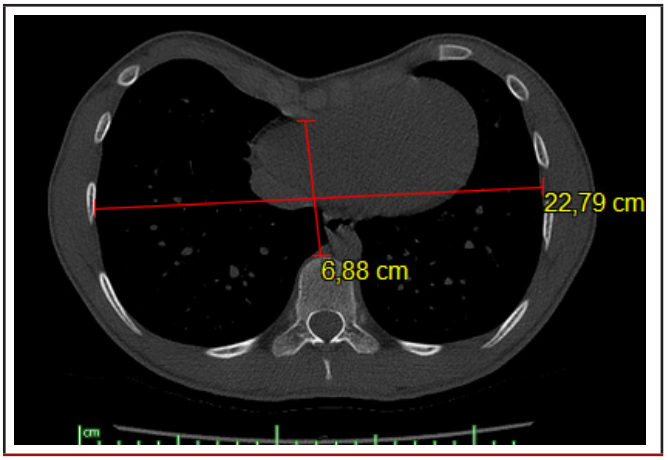

Figure-2. Haller index: maximum latero-lateral distance/ shortest anteroposterior distance.

PECTUS CARINATUM

It is the protrusion deformity of chest wall, also called as "pigeon breast" and "chicken breast" and identified by Brodkin for the first time **(Figure-3.a-b).** This is the second most often seen deformity among chest wall defects (frequency of 5 % in all deformities) and most of them become clear in middle childhood period. It has a genetic predisposition and approximately ¼ of the patients have family history of chest wall deformity; congenital heart disease, marfan syndrome, scoliosis (15%), kyphoses and musculoskeletal defects can be seen [17,27].

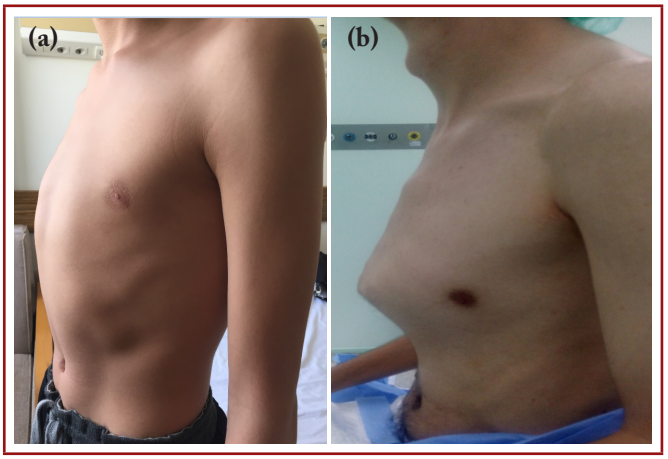

Figure-3.a,b. Two cases with pectus carinatum deformity

Pectus carinatum consists of single-sided or bivious involvement of costa cartilages and deforming spectrums that is on sternum's upper or lower eminentia. Complex deformity can also be seen. It may occur due to cartilage depression at one side, cartilage protrusion at other side and rotation of sternum.

The most seen clinic appearance of this deformity is the protrusion of sternum object and the symmetric protrusion of lower costal cartilages. Asymmetrical deformity which occurs due to unilateral protrusion of costa cartilages appears less frequently and mixed type deformity is seen less often.

Also, upper or kondromanubrium deformitie can occur although it is unusual. Here, manubrium prominence and upper costal cartilages are held and the relative depression of sternum object is seen.

An etiology of pectus carinatum is unknown. It occurs three times higher in boys than girls. Unlike pectus excavatum, it generally appears in childhood and adolescence. Pectus carinatum is seen only in 3 patients in labour. Almost half of the patients face it at the beginning of puberty.

26 % of the patients who suffer from pectus carinatum have a family history having chest wall deformity. 15 % of the patients also carry scoliosis and 12% of them have family history including some level of scoliosis. The patients having scoliosis or quite severe deformity can be suspected of having Marfan syndrome.

Pectus Carinatum is put under 4 types called Kondroglandial symmetrical type, Kondroglandial asymmetrical type, mixed type including Carinatum and excavatum together and Kondromanubrial type (Pouter Pigeon, Currarino-Silverman syndrome). Kondrogladiolar type is the most seen type with the percentage of 89 % [22]. It is like the middle of sternum (gladiolus), the lower part of it and the forward protrusion of costal cartilages in that area [20]. With this deformity type, lateral depression (small burn, Harrison's sulcus) typically exists in costas [17].

MIXED CARINATUM AND EXCAVATUM

On one side carinatum deformity is observed, on the other side excavatum deformity or depression together with sternal rotation is noticed.

CHONDROMANUBRIAL

It is the most rarely seen form. This form is typically named as pigeon chest deformity and in this form, while protrusion bears on upper sternum corpus part and upper 2nd and the 3rd cartilage costas, the lower part of sternum purports as depressed. Cardiac anomalies are seen more in this form.

POLAND SYNDROME

In 1841, this syndrome took part in literature the publication of Alfred Poland, a medical student in Guy's Hospital studying on an old convict George ELT, 27. He realized that cadaver does not have major and minor muscles in his cartilage and that there is an anatomic deformity characterised with syndactylia. Since 1962, patients who have this illness have been called as Poland Syndrome.

Poland syndrome is characterized with mamma retention, the full absence of papilla (amastia) or athelia hypoplasia, hypoplasia of subcutaneous tissue, subcutaneous oil and axillary hair development together with scantiness of pilosity on the front chest wall, lack of costa, the absence of costosternal piece of pectoralis major muscle or its hypoplasia, the absence of pectoralis minor muscle and costal cartilage, the hypoplasias or aplasias of serratus, external oblique, latissimus dorsi, infraspinatus and supraspinatus and upper extremity anomalies (syndactylia, brachydactyly or ectromelia) that accompany on the same route. It occurs 2-3 times more in men than women. Although its incidence is reported differently on varied series, it's average is between 1/30.000-1/32.000. It is seen twice as much on the right side than on the left side [3,10,19,20].

Although there is not exact conclusion about its etiology, there are two main hypotheses on certain periods of pregnancy. The first one among these is mesodermal plateau damage that is thought to appear in 3-4 weeks of pregnancy or developmental disability [24], or the other one, which is the cut of blood stream in subclavian and vertebral systems during the 6-7 weeks of pregnancy [2]. Besides familial facts have rarely been reported in literature, "late dominant germ cell mutation" is also a claim that is being discussed [3,5,6].

STERNAL DEFECTS

These defects are less commonly encountered compared to pectus type deformities. Especially the situations where the heart is located outside the thorax are considered lethal [8].

1. Basic Cleft Sternum:

The heart is in correct position however, there is a defect in sternum joint located at the frontal thoracic wall. Usually the surrounding tissue and pericardium carries wild type traits. The pulsations from the heart are clearly visible at the sternum defect area. There is a complete or partial separation in the sternum. In the cases of crying or valsalva maneuver, the deformities appear more visible [12,27].

2. Ectopia Cordis:

This case is quite rare (5-7 % per million organisms). The most common types are thoracic and throracoabdominal.

Cervical Ectopia Cordis:

Can only be distinguished from Thoracic Ectopia Cordis by the superior positioning size of the heart. Cervico-facial anomalies are common. This case is lethal.

Thoracic Ectopia Cordis:

First case was reported by Stenson (1671) [20]. In this situation, the newborns have the contractile heart located outside without the surrounding tissue. Usually bears additional cardiac malformations. In addition, probands may also show abdominal wall defects such as omphalocell, diastasis recti and eventration.

Thoracoabdominal Ectopia Cordis (Cantrell's Pentalogy):

Sternum is incised and the heart is outside the thorax in the front. This anomaly was first reported by Wilson (1798) and the pentalogy was described by Cantrell (1958). This anomaly consists of distal sternal cleft, ventral omphalocell, absence of anterior diaphram, absence of pericardium facing the diaphram side, cardiac abnormalities (VSD, Fallot tetralogy, ventricular diverticule etc.). Invasive methods after prenatal ultrasound scans could not decrease the mortality rates in these cases. In addition to the lethal effects of all the defects listed, pulmonary hyperplasia can also lead to increased lethality [22]. The initial operative methods should consist of targeting the tissue defects in the abdominal cavity and the heart. So as to prevent infections and mediastinitis, the primer excision and tissue coverage of the omphalocell should be preferred. The compensation of the abdominal wall can be achieved by mobilizing the wall with flebs or supporting of the wall with prostetic materials. Repair of this locus is easier than Thoracic Ectopia Cordis. Moreover, repair of the cardiac defects should be performed before the heart is supported by prosthetic materials.

OTHER DEFORMITIES

Can progress as parcial development or agenesis in more than one costa. Bifurcasions and fusion abnormalities are common in costas. These abnormalities usually do not cause functional or estethical defects. In advanced cases, pressure can form around cifoeskoliose and intrathoracic organs.

Thoracic Deformities in Diffuse Skeletal Defects

Asphyctic Thoracic Dystrophy (Jeune Disorder):

This is an otozomal recessive disease with no shown chromosomal abnormalities. There is a bell-shaped rigid thorax and a remarkable abdominal structure. The transverse and the antero-posterior diameter of the thorax is shorter. The ribcage is short and wide, and horizontally positioned. All bones are shorter and wider. Extremities are also shorter and pelvis is narrower.

Spondylothoracic Dysplasia (Jarcho-Levin Syndrome):

Characterized by its autosomal recessively transmitted defects like multiple vertabrate, rib abnormalities and breathe obstruction. Since vertabratae are short and the presence of fusion in the posterior ribs in the thoracic vertebrae. Rigid congenital kyphoscoliosis is seen. Pulmonary infections are common. Post-natal lethalities are also common.

Cerebralcostomandibular syndrome:

It was reported in 1966 for the first time. The underlying reasons and genetic causes are not well known. There are three primary observations. Mental retardation, gaps between ribs and micrognathia prognosis. 40% of the probands fail to survive due to breathing defects.

TREATMENT MODALITIES IN PECTUS DEFORMITIES

CONSERVATIVE TREATMENT

1-Dynamic compression orthoses (Argentina brace)

Treatment with dynamic compressive orthoses (DTC – dynamic thorax compressor) was first described in 1979 for pectus carinatum [9,13]. Treatment with DTC orthoses, which have screws on the sides instead of velcro or fasteners and allow for the gradual compression of protruding areas, was described by Haje et al. not only for pectus carinatum, but also for pectus excavatum, starting in 1992 [4]. In 2006, the authors synthesized the description of the method by publishing the term "dynamic remodeling (DR) method" to designate the use of DTC orthoses during exercises that promote increased intrathoracic pressure. The overall percentage of children and adolescents with [25] and [15] improvement was 60.6 %.

Especially, these corsets are suitable for patients with pectus carinatum deformities (Figure-4.a,b) These are also recommended for patients for whom nucs pectus carinatum or operation options are not available. In a prospective recent case study with 114 dynamic pectus carinatum cases using a compression corset, 8,80 ± 3,94 month usage led to 64 % success and 15 % fail rates with 21 % of the patients with necessity of continuity. In addition, asymmetric and elderly patients who fail to use the corset regularly showed no progression of elimination of the deformities [9].

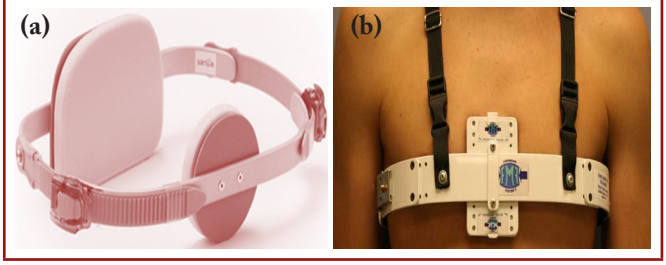

Figure-4.a,b. Dynamic compression orthoses

2- Vacuum Bell Treatment:

It was first described by Eckart Klobe. This method is a major non-invasive approach where symmetrical and light operational methods fail in cases with pectus excavatus. It consists of a system with a vacuum and is applied on the chest and is adjustable to fit (Figure-5).

In the first treatment session 15 minutes of application is sufficient. The patient can continue applying the treatment at home under supervision from a physician. 1-2 hours of application a day was reported sufficient for young and adult patients.

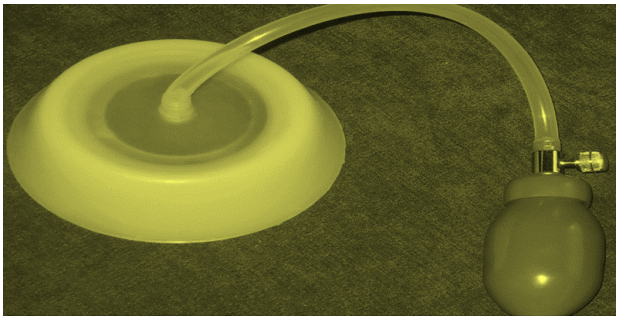

Figure-5. Vacuum bell system

SURGICAL APPROACH

Open Surgery

Operational surgery on Pectus Excavatum, was carried out by Meyer (1911) and Sauerbruch (1913) for the first time.

In 1949, the modified method derived from this technique was defined by Ravitch.

1. Excision of deformed rib cartillages with their perikondria
2. Separation of xifoides from sternum
3. Separation of intercostel (rib) bands from sternum
4. Transverse sternal osteotomie (Figure 6 a-e)

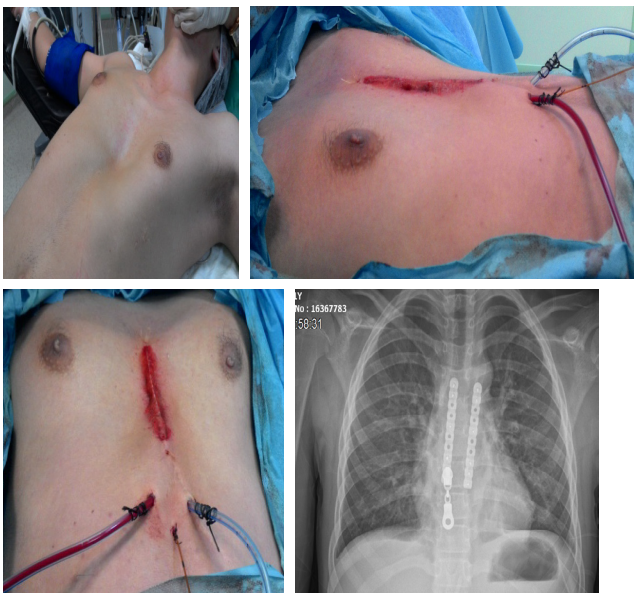

Figure-6. a-d. Operative view of a case who had Ravitch operation due to pectus excavatum. (Courtesy of Ali Cevat Kutluk, MD)

This technique allows swapping the kirschner string with sternum. In 1957 and 1958 respectively, Baronofsky and Welch indicated andother technique. In this technique, the main steps are protection of pericondrial sheaths on rib cartillages, dorsal intercostal bands, sternal osteotomie, fixation of the sternum to anterior structures by silk stiches. This technique was reported to have high success rates.

In addition, in 1957, a tripod fixation method was described by Haller. This strategy follows the posterior sternal osteotomie, subpericardional resectioning of the lower cartillage deformities, posterolateral oblique division of normal secondary and tertiary costal cartillages. In 45 cases, the success rate was reported as 100%.

Sternal turnover technique was also reported first in Japan. Sternum was twisted 180 degrees as a free-greft and reattached to costal cartillages. This radical approach was considered limited due to its potential for high complications in children with pectal excavatum. Sternal necrosis is also one of the rare complications.

Operational Repair of Pectus Carinatum

First repair was carried out four decades ago. In 1952, Ravitch reported the repair of condromanubrial bud. He managed this repair by resecting the costal cartillages followed by carrying out double ostetomie in the sternum.

Modern techniques were first applied in 1963. This method consisted of subpericondrial resection of the costal cartillages and resection of lower sternum and the strengthening of the rest of the sternum with the rectus muscle. Afterwards, in 1973, a more elaborate method was developed based on subpericondrial resection of the budding costal cartillages and protection of the whole sternum.

In today's medical approaches, a transverse osteotomie by frontal cortex of the sternum and with replacement of the sternum from anterior to posterior benefiting from the posterior cortex fracture and correction of the frontal protrusion.

Surgery options in Poland Syndrome

In the cases of missing ribs and paradoxal movements of the ribcage, approaches improvement of the skeletal system and support of the ribcage are commonly used. Methods involving repair of the missing ribs, correction of assymetries in the sternum by transverse osteotomie, improvement of stabilization by by marlex mesh besides costa grefts or repair of the chest wall by marlex mesh sandwich method are among the strongest approaches [19].

in order to solve esthetic problems, autogenous tissue transfer or patient-specific silicone implants are usually recommended. Lately, the methods involving injection of fat as main or side approaches are becoming more and more common [6,16].

Implants provide easy and fast options that are also most commonly used. When implants are decided to be used, a pattern is prepared on top of the patient by plaster or a 3-d computer model is created.

Poland syndrome and its side deformities define the patient's functional and esthetic requirements. The priority is to protect the heart and the lungs by increasing stability of the ribcage. Therefore, patient-specific solutions should be evaluated and after considering patient's opinion and requirements, unique methods should be applied supporting the symmetric and secure body shape [3,6].

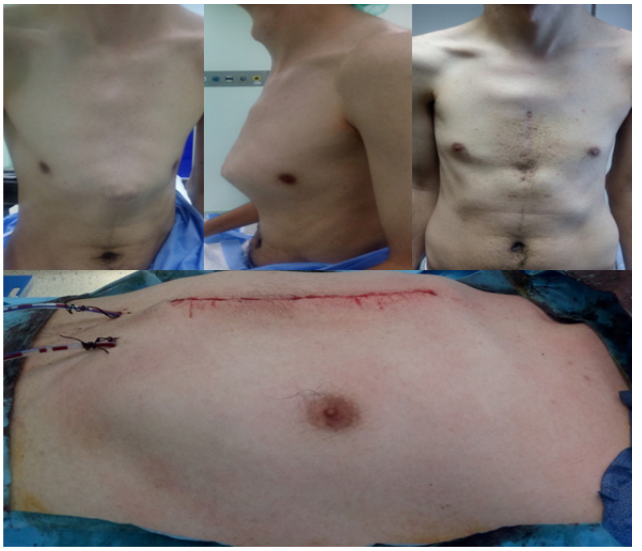

Figure-7.a-d. A case who had Ravitch operation due to pectus carinatum. (Courtesy of Selcuk Kose, MD)

Minimal Invasive Surgery

1-Nuss Method (minimal Invasion in Pectus Excavatum)

A technique was reported with resection of sternum retrosternal barring of the costa cartillages or elevation without division (nuss method) **(Figure-8.a-d).**

This method was improved after years and an almost perfect version was created **(Figure-9.a-c).**

In a study carried out by Nuss [26] between 1987-2008 consisting of 1015 cases showed that the most common complication is the spontaneously recessing pneumothroax. misplacement of the bar and infection are also common risks however, the incidence was reported as less than 1 %. The most dangerous complication is the rare cardiac rupture. recovery phase is between 4-5 days. Pain control, pulmonary function physiotherapy and educational support should always be considered in the cases. The epidural catheter to control the pain is critical and can be kept for 2-4 days depending on the situation. For maintenance

of the situation, oral or parenteral analgesic administration is recommended.

After discharging of the patient, a 6-week restriction plan is applied on physical activities and excersize including an initial 2-3 week ban for work/school activities.

The bar on the pectus is usually removed under general anesthesia after 2-4 years without any reported complications so far. patients are sent home after 2 hours post-operation. Reoccurrence rate is below 5% after all these implications are carried out.

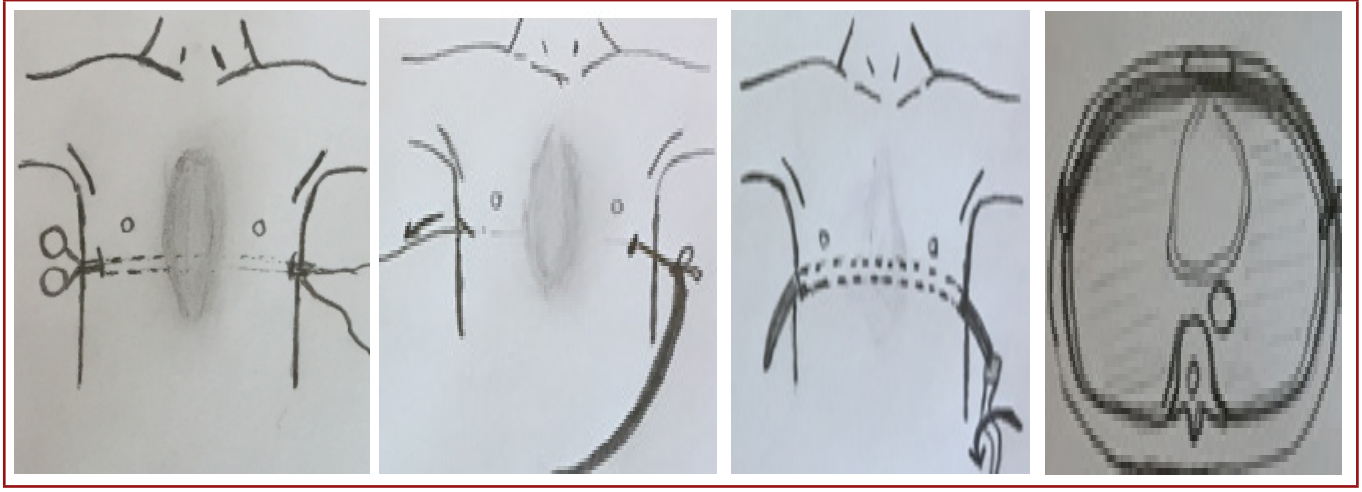

Figure-8.a-d. The steps of Nuss operation

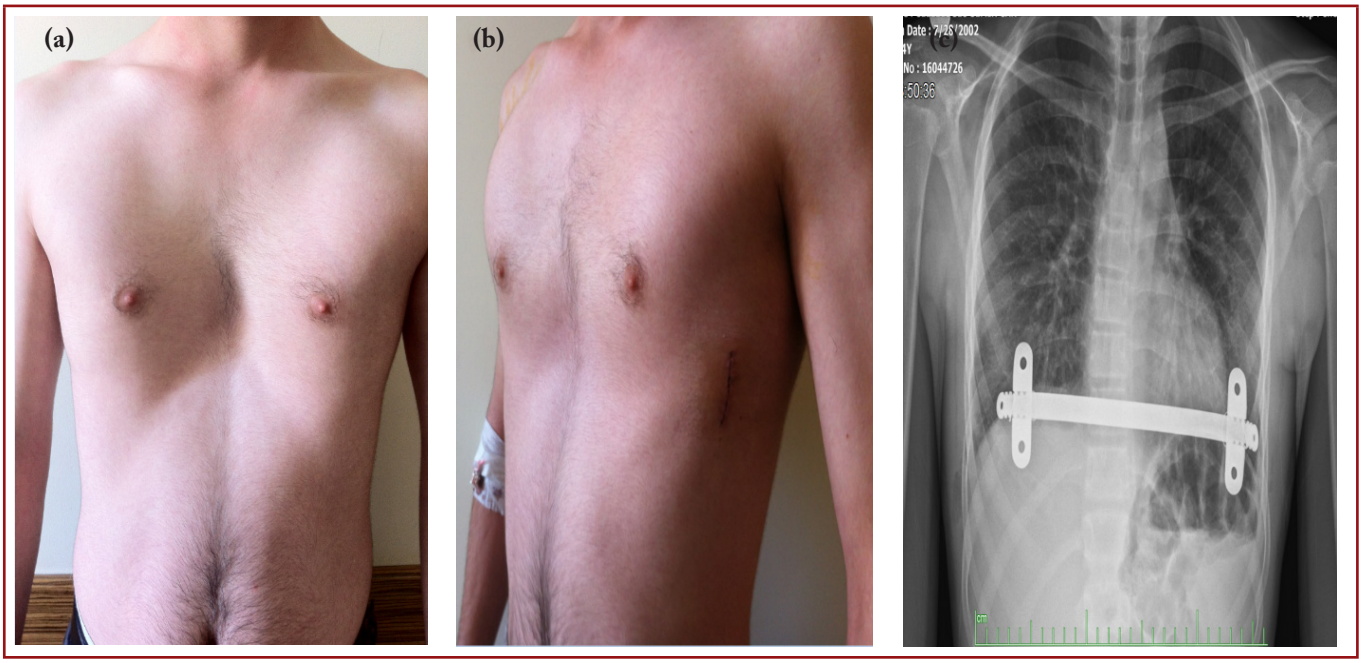

Figure-9.a-c. Preoperative view of a case with pectus excavatum **(a)**. Postoperative radiograph and view after Nuss operation **(b-c)** (Courtesy of Levent Cansever, MD)

2- ABRAMSON METHOD
(Minimal Invasive Surgery on the Pectus Caritanum)

Dr. H. Abramson is the first scientist to perform a modified version of the Nuss method on 40 pectus caritanum patients and present the results in scientific congresses [1]. (**Figure-10.a-c**).

In this technique, quite similar to Nuss method, success rate is high in pectus caritanum patients as mentioned. In this method, the tunnel formed with the bars is used to pressure the sternum where the budding is most visible and on both sides, attached to the ribs by steel strings using screws. The bar remains attached for approximately 2-3 years and removed under general anesthesia together with the screws [13].

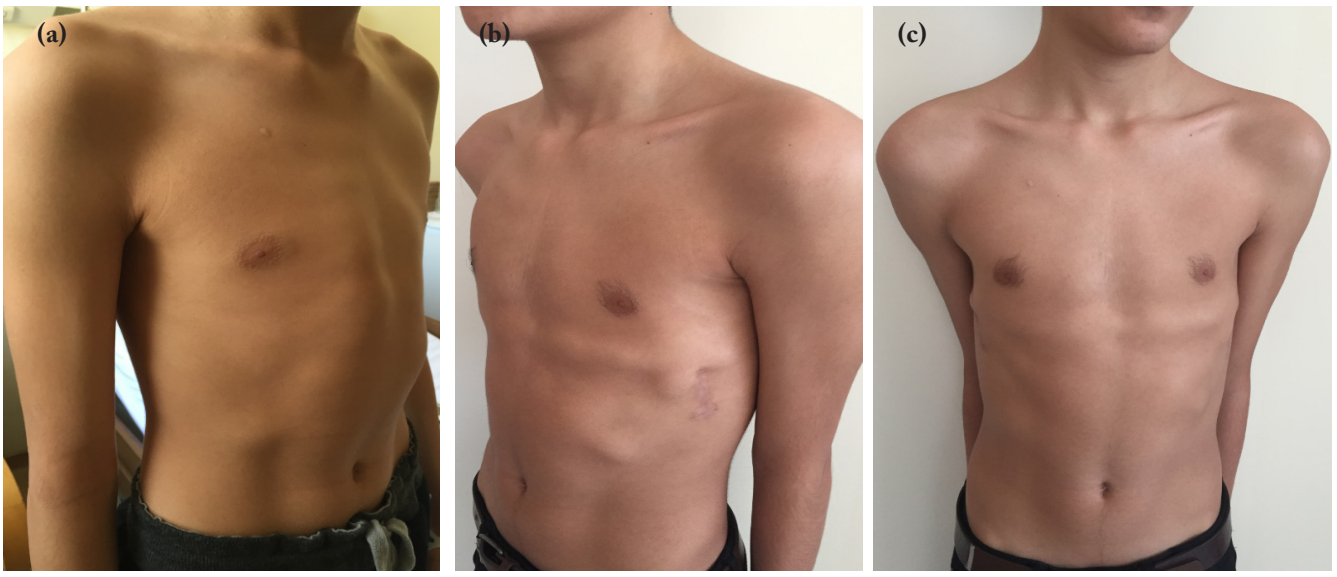

Figure-10.a-c. Preoperative view of a case with pectus carinatum **(a)**. Postoperative view after Abramson operation **(b-c)** (Courtesy of Levent Cansever, MD)

CONCLUSION

Anterior chest wall deformities, known universally as pectus deformities, are often observed in medical practice. These deformities are usually hidden by patients due to psychological problems, allowing them to remain unknown. As recently as 1990, anterior chest wall surgery was considered to have matured with no new innovations. Suddenly this has become an exciting and dynamic area of surgery with new ideas and innovations being prescribed at conferences and in medical journals almost on a monthly basis. Since the publication of Donald Nuss about the success of the minimally invasive repair of pectus excavatum (MIRPE) in 1998 the demand for correction of all sorts of thoracic wall deformities boomed almost all over the world [4].

Scoliosis of the vertebral column is associated with chest wall anomalies. There is however still lack of knowledge about the pathogenesis of thoracic anomalies going along with scoliosis, whether they are expression of a secondary reactive deformation based on compelled biomechanical forces due to heavily distorted and multiaxially shortened thorax or if they are genetically contingent and accompanied with the scoliosis deformity itself. Likewise pectus excavatum deformity has been reported to be associated with thoracic scoliosis in 15-20% of cases. Moreover thoracic scoliosis can usually be seen after open correction of chest wall deformities but it has been reported even after minimal invasive (Nuss) correction of the deformities[23].

The conservative treatment option for pectus deformities is based on the principles of Nicolas Andry, considered "the father of orthopedics," and the effects of this treatment can be explained by Julius Wolff's law of bone remodeling. Therapeutic forces applied regularly on deformed bones and cartilage may produce a gradual remodeling in a beneficial and corrective direction, and this can be observed especially in the anterior chest wall, which is a flexible region [14].

The MIRPE due to several advantages remains as the ideal therapeutic option in childhood and adolescence, even in selected cases in adulthood. Nevertheless the more rigid and more severe the deformity appears beyond puberty, the hybrid technique MOVARPE seems to represent an alternative method with lesser pain periods, lesser pectus bar implantation period, and a lower rate of common complications, to be noted at first a tilting of the bar [7,11].

Nevertheless, many of the techniques described so far should be performed only at specialized centers, which fulfill the requirements of broad experience by sufficient numbers of

cases treated. However, conclusive studies are still lacking due to variable surgical expertise or inhomogeneous patient collectives, thus the proper selection of the most appropriate techniques for a multitude of indications sometimes remains cumbersome.

REFERENCES

1. Abramson H, D'Agostino J, Wuscovi S. A 5-year experience with a minimally invasive technique for pectus carinatum repair. J Ped Surg 2009; 44(1): 118–124.
2. Bamforth JS, Fabian C, Machin G, Honore L. Poland anomaly with limb body wall disruption defect: case report and review. *Am J Med Genet* 1992; 43: 780-784.
3. Bayramiçli M. Poland sendromu. *Toraks Cerrahisi Bülteni* 2011; 2: 229-235.
4. Beirão ME. Tratamento conservador do pectus carinatum com uso de órtese. *Rev Bras Ortop* 1999; 34(11/12): 575-578.
5. Bouvet JP, Leveque D, Bernetieres F, Gros JJ. Vascular origin of Poland's syndrome? A Comperative rheographic study of the vascularization of the arms in eight patients. *Eur J Pediatr* 1978; 128: 17-26.
6. David TJ. Familial Poland anomaly. *J Med Genet* 1982; 19: 293-296.
7. .Emil S, Sévigny M, Montpetit K, Baird R, Laberge JM, Goyette J, Finlay I, Courchesne G. Success and duration of dynamic bracing for pectus carinatum: A four-year prospective study. J Pediatr Surg 2017; 52(1): 124-129.
8. .Engum SA. Embryology, sternal clefts, ectopia cordis and Cantrell's pentalogy. *Sem Ped Surg* 2008; 17: 154-160.
9. Erşen E, Demirkaya A, Kılıç B, Kara HV. , Yakşi O. Alizade N , Demirhan Ö, Sayılgan C, Turna A , Kaynak K. Minimally invasive repair of pectus excavatum (MIRPE) in adults: is it a proper choice? Videosurgery and Other Miniinvasive Techniques 2, June, 2016.
10. Fokin AA, Robicsek F. Poland's syndrome revisited. *Ann Thorac Surg* 2002; 74: 2218-2225.
11. Günay E, Simşek Z, Güneren G, Celikyay F. A rare case of isolated complete congenital sternal cleft. Anadolu Kardiyol Derg 2010; 10: E3.
12. Haje SA, Raymundo JLP. Considerações sobre deformidades da parede torácica anterior e apresentação de tratamento conservador para as formas com componentes de protrusão. *Rev Bras Ortop* 1979; 14(4): 167-178.
13. Haje SA, Antunes EJ, Raymundo JLP, Dourado JN. Pectus carinatum: enfoque atual. *Rev Bras Ortop* 1988; 23(9): 257-264.
14. Haje SA, de Podestá Haje D. Orthopedic approach to pectus deformities: 32 years of studies. *Rev Brasil Ortopedia* 2009; 44(3): 191-198.
15. Kelly RE Jr, Shamberger RC, Mellins RB, Mitchell KK, Lawson ML, Oldham K. Prospective multicenter study of surgical correction of pectus excavatum: design, perioperative complications, pain and baseline pulmonary function facilitated by internet-based data collection. *J Am Coll Surg* 2007; 205: 205-216.
16. Knoetgen J, Johnson CH, Arnold PG. Reconstruction of the Chest. In: Mathes SJ, Vincent ED, R. Hentz R (Eds.). *Plastic Surgery*. 2nd Ed., Vol-VI, Saunders Elsevier, New York 2006; pp: 411-537.
17. Kuhn MA, Nuss D. Pectus Deformities. In: Mattei P (Ed). Fundamentals of Pediatric Surgery. Springer, New York 2011; pp: 313-322.
18. Lopushinsky SR, Fecteau AH. Pectus Deformities: A review of open surgery in the modern era. *Sem Ped Surg* 2008; 17: 201-208.
19. Poland A. Deficiency of the pectoral muscles. Guys Hosp Rep 1841: 6; 191-193.
20. Sarper A, Demircan A. Konjenital Göğüs Duvarı Anomalileri. In: Ökten İ, Güngör A. (Eds.). *Göğüs Cerrahisi, İstanbul* 2003; pp:699-724.
21. Saxena AK. Pectus excavatum, pectus carinatum and other forms of thoracic deformities. *J Indian Assoc Pediatr Surg* 2005; 10: 147-157.
22. Shamberger RC. Chest Wall Deformities. In: Shields TW, LoCicero J, Ponn RB, Rusch VW (Eds.). *General Thoracic Surgery*. Vol. 1, 6th ed., Lippincott Williams and Wilkins, Philadelphia 2005; pp: 653-681.
23. Schwabegger AH (Ed). Congenital thoracic wall deformities. Diagnosis, therapy, and current developments. Wien 2011 Springer-Verlag; pp:21-56.F
24. Pinsolle V, Chichery A, Grolleau J-L, Chavoin JP. Autologous fat injection in Poland's Syndrome. *JPRAS* 2008; 61: 784-791.
25. Williams AM, Crabbe DCG. Pectus deformities of the anterior chest wall. *Ped Respir Rev* 2003; 4: 237-42.
26. Yiyit N. Poland sendromu. 10.5606/tgkdc. dergisi.2015.10124
27. Yüksel M, Yıldızeli B. Göğüs Duvarı Deformiteleri. In: Yüksel M, Kalaycı G (Eds.). *Göğüs Cerrahisi*. İstanbul 2001; pp: 559-580.

Volume: 28, Issue: 3, July 2017 pp: 205-214 FRONTIERS OF SPINAL SURGERY

SPINAL FRACTURES AND DISLOCATIONS IN THE KITĀBU'L-ḤĀVĪ (LIBER CONTINENS) BOOK OF THE RAZI*

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In memoriam of UNESCO 2016, 1150th anniversary of the birth of Muhammad Zakariyā Rāzī (also known by his Latinized name: Rhazes or Rasis), physician, chemist and philosopher (866-925).

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SUMMARY:

Abū Bakr Muḥammad b. Zakariyyā al-Rāzī was one of the most scientific figures during the era called Golden Age of civilization and medicine in Islamic world. He was a scientist who made important contributions to both Eastern and Western medieval scientific world with his works. Evaluation of the sections on spinal fractures and dislocations in Rhazes' al-Ḥāwī fī al-Ṭibb, which was a huge work formed by his pupils after his death using his notes recorded by Rhazes when he was alive, is aim of this study.

The sections regarding the spinal fractures and dislocations were determined in the 13th part of al-Ḥāwī fī al-Ṭibb in Arabic and 15th part of Liber Continens in Latin, which contain subjects on fractures, dislocations, injuries and their treatments and medicines, and translated from Arabic and Latin into English. Results were presented and what these findings mean in the history of medicine was discussed in the article.

Key words: Al-Hawi fi al-Tibb, Al-Razi, Liber Continens, Rhazes, spinal dislocations, spinal fractures.

Level of Evidence: Historical article, Level V.

INTRODUCTION:

Abū Bakr Muḥammad b. Zakariyyā al-Rāzī (Figure-1)[40], known as Rhazes in the West, was born in Rey, near Tehran. Historians consider him a gifted physician and a brilliant chemist [28,38] and at the same time he is acknowledged as one of the Islam's most freethinking philosophers [15]. In his early life Rhazes first dealt with music and then educated philosophy. At a relatively advanced age he started to study medicine in Rey, afterwards he travelled to Syria, Egypt, and Andalusia. Some sources claim that Rhazes stayed in Cordoba for a long time and upon turning back from Andalusia he first worked in Rey and then became director and surgeon general of one of the major hospitals in Baghdad [5,37]. One historian of medicine on the other hand argued that the information about Andalusia period is incorrect and that that was mistakenely passed from Africanus Leo [23].

Figure-1. Portrait of Abū Bakr Muḥammad b. Zakariyyā al-Rāzī [40].

After working in Baghdad many years he entered the service of Manṣūr ibn Isḥaq, the ruler of Khorassan

and Transaxonia in Central Asia [5,37]. Towards the end of his life he developed vision loss due to probably cataract in his both eyes [5-6,8,18,37]. Rhazes refused the surgical intervention owing to the doctor's lack of knowledge of the whole anatomy of the eye [5-6,37]. The anecdote regarding this event from famous historian Abū al-Faraj is below:

"The great physician Rhazes became blind in the late phase of his life. He called kaḥḥāl [Eye doctor; occulist] [11] *for inspection of his eyes. After carefully examining the eyes of Rhazes the doctor found out the cause of blindness and explained that a surgical procedure was needed, and he could carry out this operation as any skillfully eye doctor would perform. In return, Rhazes said that he would only accept the surgical procedure if the eye doctor could name the anatomical layers of the eye. While the doctor knew little about the detailed anatomy of the eye he could not answer the quest properly, whereupon Rhazes said: How could a man open my eyes when he even does not know the thorough anatomy of the eye? I have seen enough of the world; I am tired of seeing it. Without suffering any grieve and sorrow I may console myself for being blind*[5]*."*

This account proved Rhazes' disciplinized and rigorous personality. On the other hand Abū Rayhān Muḥammad b. Aḥmad al-Bayrūnī (973-1048), known in the West as Alberuni or Alboron, wrote another story about this event. According to al-Bayrūnī [6] a disciple of Rhazes had arrived from Ṭaberistān to treat teacher's vision problem.

Then, Rhazes asked him how he can cure his eye condition and the disciple explained what he can do. However, Rhazes replied as

"God is my witness that there is nobody who can surpass you as ḳaddāḥ *[The operator who performs upon the eye the operation of couching].* [22] *Moreover, you are the best kāḥil [should be kaḥḥāl]. However as you know this procedure cannot be done without pain. It needs a long lasting course. The soul would get tired. This long time may give tediousness. Sometimes, this long treatment time can outdo man's lifetime. Sometimes, death time comes closer. An ugly man like me shows up and turns the beauty into bitterness or disturbs tranquility with pains*[6]*."*

According to these accounts Rhazes never underwent an eye surgery. Rhazes was a very productive writer; he authored more than 200 books in his life span [35,38]. Half of them were composed on medicine [38]. The best known of his work is *Kitāb al-Ḥāwī fī al-Ṭibb,* recognized in the West as *Liber Continens* (Figure-2) [10-11,25,38]. This work was an extensive medical encyclopedia [10-11,29,35,38] and summarized mainly from previous Greek, Syriac, Arabic, Persian, and Hindu physicans' works. Additionally, Rhazes included his own observations and opinions [29,38,41]. Rhazes' disciples organized the book and sections in a successive manner after his death [10,29,41].

In *Liber Continens* Rhazes quoted first the former physiscian followed by his own opinion usually under the captioning "To Me" or "My Own" (lī) or "I said" [29]. The work had affected Eastern and Western medicine greatly starting from its writing time. In Europe, Farragut of Sicilian [28] / Antiochian [4] first translated *Liber Continens* in 1279 from Arabic into Latin for King Charles of Angevin Dynasty. Much later in 1486 it was published under the name of *Liber dictus Elhavi,* in Brescia, northern Italy [4,10,29], and then in Venice in 1500, 1506 and 1542 [29].

Figure-2. *Liber Continens,* published by Ottaviano Scotus in Venice in 1529 [25].

Liber Continens had been one of the essential medical encyclopedic sources in some European universities until 17th century [4,17,41]. One other noteworthy medical work of Rhazes was *Kitāb al-Manṣūrī fī al-Ṭibb* that was dedicated to Khorassan governor Manṣūr ibn Isḥāq (4,8,36,41). It was translated into Latin by Gerard of Cremona under the name *Liber medicinalis ad Almansorem* [10-11] and was first published in Milan, 1481 [36].

Rhazes created *Liber Almonserem* as a short compilation largely based on Greek medicine [10] containing only 10 topics over the most important medical issues of the time [10,36,38]. The seventh

(*On Surgery*) [11,24] and the ninth (*On the Treatment of All Diseases*, known also as *Nonus Almansoris*) sections of *Liber Almonsorem* are the most valuable sections of this work [10-11,36,41].

*Kitāb al-Jadarī wa'l-*Ḥa*ṣba* was considered as the most original one of his works [10-11,28,35,36]. It was the first documentation of smallpox and measles in history [8,36]. Sarton [38] argued that *Kitāb al-Jadarī wa'l-*Ḥa*ṣba* was the masterwork of the Islamic medicine. It was named as *Liber de Pestilentia* in Latin [8,11], however its better known title is *On Smallpox and Measles* [28,35-36].

This work proved that how Rhazes was an excellent observer and how he was a skilled compiler and also critic of Greek, Syriac and early Arabic medicine and finally how he became famous [29]. Rhazes was also the first physician in history who wrote specifically on pediatric diseases [4,33].

The other work he created was *Kitāb fī* Ṣ*ifāt Bīmāristān* that essentially dealt with where to establish and built, and also how to organize and manage hospitals [4-5,34]. At the same time he wrote on the ethics of physicians, named *Akhlāq al-*Ṭ*abīb* [4,19] and fought also against quacks and ignorants in his other work [5,34-35]. While Rhazes followed Galen in theory he was a determined Hippocratist in practice. At the same time Rhazes was a well-known alchemist and usually employed newly therapeutic chemical compositions [29,38]. Rhazes effectively combined his knowledge of chemistry with medical practice and could be considered therefore as "the Ancestor of Iatrochemists" [38]. Rhazes was also the first physician who mentioned about alcohol [5].

This work is designed to consider the sections written on the fractures and dislocations of the spine in *Liber Continens*.

MATERIAL AND METHOD

Two Arabic copies of Fascicule 13 of *Kitāb al-*Ḥ*āvī fī al-*Ṭibb1,31 and also one Latin hardcopy of Part 15 of *Liber Continens*30 were studied to obtain the sections related to fractures and dislocations of the spine.

Two Arabic copies of *Kitāb al-*Ḥ*āvī fī al-*Ṭ*ibb* were searched by using keywords "خرزة / kharaza While . "(vertebrae) fiqarat / تارقف" and "(spinalis medulla) nukhaʿ / عاخن" ,"(spine) sulb / بلص" ,"(vertebra) second copy was in PDF the mentioned keywords were searched at the same time electronically on computer. The parts where these words are found were identified and compared with the Latin version. Arabic and Latin texts were included to the text as separate files.

The cases regarding spinal injuries in the first book of *Liber Continens* were omitted in this study because *The Kitāb al-*Ḥ*āwī of Rāzī (ca. 900 AD), Book One of the* Ḥ*āwī on Brain, Nerve, and Mental Disorders: studies in the transmission of medical texts from Greek into Arabic into Latin* published in English as doctorate of philosophy thesis by Jennifer S. Bryson already included these sections [9].

All quotations from Arabic and Latin versions were translated in verbatim by being faithfull to original texts. All texts in Appendix-2 were quoted from the liber XV of *Liber Elhavi, seu Ars medicinae* [30]. Since there were no page numbers in original text, there are no references to the page numbers of the quotations.

In certain parts of those spine related articles Rhazes specified his own thoughts under the captioning "to me" or "my own" (ل / lī) after quoting a former physician's opinion. These sections are presented as following.

RESULTS

The twelfth article from Manafiʿ al-Aʿḍā'

This section was excerpted from Galen's *De usu partium corporis humani libri XVII* [2] */περὶχρείας τῶν ἐν ἀνθρώπου σώματι μορίων ιζ"* [39] / *On the Usefulness of the Parts of the Body* [14] that concludes that any dislocation at the level of atlanto-occipital joint can induce disfunction of the respiratory nerve that may consequently cause sudden death.

"He said: When it occurs to the first articulation, i.e. the first one of the cervical vertebra, which conjoined to the head, dislocates, the animal dies immediately, due to the breath arrest, because the breath supplying nerve is deprived of its action (1,p.111;30;31,p.1327).

Rhazes wrote:

"I say: When the nerve is knotted, something appears that resembles the nodule on the hand and the foot close to the joints. Frequently this occurs after severe tiredness. There is a distinction between the knot and the nodule, because knot is more inseparable from its place than the nodule and touching it is such as touching the nerve. And when it is compressed violently, it disappears and goes away and some of them come back. The treatment is to oppress on it, if it disperses by oppressing, otherwise it is pounded with a hammer and a wood / (small wooden hammer), then a splint is put on it and lest it does not return it is bound strictly, and if it magnifies or becomes abundant, the body should be purged. And perhaps it may be large but plain such as in inner side of woman's knee, because it was in bone of the hand, it was dispersed via oppression then it was bound and went away. When you see and doubt about it, ask him if it occurred after tiredness [or not] and look at if touching of it is such as touching of nerve and oppress on it and inspect if this oppression effects it till wither it [or not] (till you have a firm opinion on it) (1,p.111-112;30;31,p.1327)."

In his remark on this subject Rhazes did not reiterate the disastrous breathing problem, he commented more about the "node of the nerve" or occurrence of a "ganglion cyst".

This description could mean either traumatic edema of the connective tissue (e.g. tendon) or muscle spasm in the neck.

In Rhazes' time the terms nerve and tendon were interchangeably used though the distinction between them had been made centuries ago. Rhazes possibly thought that besides causing breathing problem a trauma at this location might also induce a disturbing symptom like muscle spasm in the neck. Thus, he focused on solving that condition and offered particular treatment method with hand-massage or cleaning the body through purging.

The ninth [section] from ʿArāʾAbuqrāṭ

Rhazes quoted this section also from Galen's *De Hippocratis et Platonis placitis libri IX* [38] */ περὶτῶν Ἱπποχράτους καὶ Πλάτωνος δογμάτων βιβλία θ΄* [39] and he preferred here the definition "front vertebrae" possibly referring to the anterior column of the spine. The described situation in this part is anterior vertebra dislocation. Galen emphasized that physical examination is essential for the diagnosis of this condition, since processus spinosus would not be spotted by palpation. Galen stated that same finding is also evident in the fracture of processus spinosum and that while anterior dislocation is a deadly situation for causing injury to the spinal cord the latter condition is easy to treat. Galen also explained the underlying mechanism for this type spine injury:

"He said: The anterior vertebrae dislocate and this location lowers as fractures of processus spinosi, and fracture of the processus spinosi is easy [to treat], and dislocation of the vertebrae is dangerous / fatal, because the dislocated vertebra either tears the medulla spinalis or compress it. If it [vertebra] departs, impels the spinal cord that requires violent insult and falling down a heavy material on it. And if a heavy material falls down on it or pushes it vehemently, processus spinosus of the vertebra is broken, before the vertebra goes in (1,p.113;30;31,p.1328)*."*

After Galen's opinion Rhazes suggested barely revisiting Hippocrates' work *De artuculis (reponendis) or De articulorum repositione / περὶἄρθρων ἐμβολῆς* [39] without further commenting.

"I say: Read on this topic and search for Hippokrates' Kitāb al-Mafāṣil / Liber articulorum (1,p.113;30;31,p.1328)*."*

In the following paragraph Rhazes included again Galen's views for posterior vertebra dislocation. For this type spine injury Galen recommended 3-treatment-methods all involving compression maneuver over the affected region:

"He said: The surgeon should mollify with bandage and straighten his head, then he should put a fully stuffed pillow on this place and should bind it in order to impel the head from that part to which it inclined / leaned, because mollifying and repeatedly pushing straighten the head and it is not treated in other way and health is regained. Posterior dislocation of the vertebra is treated in the same way as the bath-attendant seizes [the patient] and by putting knee on patient's back and pushing strongly and violently and returning the vertebra [to its original location] or placing him in prone position and raising up on heel until the vertebra is returned [to its original location] or rubbing with ḥūmak [probably shawbak: Rolling pin] (12) *till it becomes straight* (1,p.113-114;30;31,p.1329)*."*

At this point Rhazes placed the following remark also taken from Galen without mentioning his own comment:

"He said: If the vertebra is separated into the abdomen, certainly there is no cure (1,p.114;30;31,p.1329).

The second of the third (the fourth in Latin) [book] from Abīẓīmiyyā

This section excerpted from Hippocrates' *Epidemiorum Libri III* (38) */ ἐπιδημιών βιβλία γ'* [38-39] / *Epidemics III* (38) specified that interior [anterior] dislocation of vertebrae may cause urinary and gaita incontinence mainly due to mechanical compression onto the bladder and the bowels. Rhazes stressed that these symptoms may also occur without vertebrae dislocation when the nerves that are going to internal organs could be damaged at their emerging points from medulla spinalis:

"If vertebrae of the spine dislocate interiorly, they compress the bladder and cause swelling and retention of the urine and firstly swelling of the rectum and [then] retention of the stool. If the vertebrae do not dislocate, but there is a fault in the spinal cord from which the nerves emerge and proceed to the vertebra, the urine and the stool pass involuntarily and when the dorsal spinal cord is shaken constantly/ continuously movement of his legs weakens and his urine is retained (1,p.115;30;31,p.1330)*."*

The author of *Epidemics* informed that, spastic and flaccid conditions of some internal organs may occur after spine traumas depending on the anatomic level and also on the mechanism of the injury. The definitions of spastic and flaccid conditions may correspond modern definitions of retention and incontinence in gastrointestinal and urinary tracts, respectively. More interestingly, Hippocrates also pronounced "shaken-spinal cord condition" with which he probably indicated concussion of the medulla spinalis.

From Kitāb yunsaba ilā Jālīnūs [The book attributed to Galen]

The first citation Rhazes excerpted from that book is on the treatment of cervical vertebra dislocations:

"He said: When a man falls down on his head, perhaps his cervical vertebra moves out (1,p.120;30;31,p.1333) *."*

"He said: Let the patient lie down in supine position, then extend moderately his head upwards and straighten his vertebra by rubbing and pressing, till it becomes straight. Then put a plaster on it and fill it with the rags and apply a long splint over it from end of the

occipital bone to end of the cervical vertebrae and bind it so tightly over the head that the ligature does not fall upon the throat and unbind it every third day (1,p.120;30;31,p.1333)."

"He said: Always place the ligature on the edge of garment, because the round [ligature] / knot, since it compresses and returns / hurts, is not good (1,p.120;30;31,p.1333)."

In his comment for this part Rhazes opposes the opinon that a cushion should be placed under the armpit when a clavicle fracture accompanies cervical vertebra dislocation. He says that there is no need for supporting the armpit in that occasion:

"I say: If the particle [of the clavicle] which tends to the humerus is in upper [position], there is no need for cushion, because you wish nothing except to straighten it (1,p.120;30;31,p.1333)."

The next paragraph deals with thoracal vertebra dislocations. The quatotion from Galen describes how the management should be carried out with the application of corset-like splints in these cases:

"But in case of the dorsal vertebra, lay the patient down in prone position and straighten the vertebra by impeling. If the vertebra slides laterally, it will be better to place two splints on both sides of the vertebra and if it slides upwards, place a splint over the vertebra in order to compress it downwards. The splints should be placed from the waist / (the thigh) to the scapula, then bind it tightly (1,p.121;30;31,p.1333)."

There is also another quatotation that mentions about sacrum fractures:

"But, when the large bone [the sacrum] which is above the coccyx is broken or its muscle is cut into very small particles/pieces, one of the hips is not repositioned [to its former condition] and lessened. And, treatment of patient: He is turned into a prone position and his thighs are separately and forcefully extended by two men, while the other extends his hand not to move downwards. You and another man with you, oppress patient's knees/hips strongly one by you and one by him. When this location become straight, place a plaster on it, and put under him a ball-like solid thing made by rags in order to impel when he lies down on this (1,p.121;30;31,p.1334)."

The quatotation regarding coccyx fracture seems very explanatory and clarifies bimanual maneuver for this type lesion:

"In case of the coccyx, insert your middle finger into the anus and oppress it upwards and straighten it with the other hand from outside till it becomes straight, then plaster it and decrease the food to lessen and soften his stool, there is no need to unbind (the ligature) frequently. Regarding the bandage, you will see its mode at practice (The last sentence is not seen in Latin text) (1,p.121;30;31,p.1334)."

For these last three statements Rhazes did not expreesed his own opinions and moved on with lectures of another antique physician, Paul of Aegina.

Būlus [Paul of Aegina]

Two sections in Rhazes' work regarding symptoms of spine fractures and dislocations were quoted from Paul of Aegina's *Kunnāsh (Kunnāsh al-thuraiyā)* [39] *(ὑπόμνημα or ἐπιτομῆς ἰατρικῆς βιβλία ἑπτά)* [38].

Paul stressed here that the prognosis of the condition is poor if the medulla spinalis is involved. Especially, cervical vertebra fracture is considered a deadly situation due to respiration standstill. He emphasized that when a bony fragment penetrates medulla spinalis this should be removed and if medulla spinalis is not involved anti-edema therapy is sufficient. He also described a correction method in the case of sacrum fracture (Figure-3 and 4):

١٢٩ في الخلع والكسر والفسخ والرضه... الخ

في خرز الصلب

قال: هذه أعراض لها رض إن بلغ إلى أن يضغط النخاع عرضت رديئة، فإن كان ذلك في خرز العنق قتل سريعاً لأنه تحبس النفس، ففي هذه ـ أعني التي تنخس النخاع ـ استعمل الشق عنه وإخراج العظم الناخس. وأما إن لم يضغط فعليك بما يسكن الورم الحار. قال: والذي/يحتاج أن يخرج من كسر العظام أبداً ما كان مبرتاً البتة أو ما كان ٢٠٨ ١٣ ينخس لأن ذلك يعفن على طول الأيام فيورث قرحة وهذا يهيج الوجع والورم.

عظم الكاهل

قال: إن تقصع إلى داخل فأدخل الأصبع في المقعدة ويرفع صوته ويسوى خارج العضد. قال: وعلق اليد في العنق ليبقى لها شكلها الطبيعي ثم مر خادمين يجر أحدهما فوق والآخر من أسفله باليد، فإن لم يجتزىء بهذا المد فيربط فوقه وأسفله ويجر برباطين ثم قابلهما وأرخه وسوه ثم يربط على ما أمر أيقراط. وإن عرض الكسر بالقرب من الإبط يكون المد بلا ربط، وإن عرض بقرب المرفق فالمرفق حيل، في الجبر ينبغي أن يكون شدة الربط بحسب قلة حس البدن وشدته وينبغي أن تلف الخرق أشده على موضع الكسر ثم يذهب به إلى الجانبين وليكن الرباط أيضاً مسترخياً إن خفت ورماً أو كان هناك وجع، والمحدث من الأطباء يستعملون الجبائر بعد الرباط من ساعته ليمسك شكل ما يسوي، والقدماء كانوا يستعملون الجبائر بعد الأسبوع لأنهم حينئذ قد أمنوا الورم، وينبغي أن تحل الرباط في أول يوم أو في كل يومين وخاصة إن ٢٠٩ ١٣ عرضت حكة، فليتطل بماء حار حتى/تتحلل الرطوبات اللذاعة إلى اليوم السابع، فإذا جاوزه فليحل في كل أربع أو خمس لأنه حينئذ قد أمن الورم والحكة وهو أجود لانحتام العظم وينبغي أن تملأ المواضع العميقة ليستوي الرباط وضع الجبائر ولتوضع الجبائر حوالي الكسر ويكون البعد بينهما أصبعاً ولا تبلغ الجبائر المفصل بل يكون فيما يلي الجانب الأيسر من المفصل أصغر وأضعف ويكون أبداً في الجوانب التي تنجذب إليها الكسر أغلظ وأطول، والأجود أن تشد العضو مع الصدر تضم إليه لئلا يتحرك البتة وخاصة إن كان الكسر قرب المرفق، وإن عرض ورم حار استعمل التطل بالزيت ولطف التدبير في أول الأمر وغلظ بآخره، وإذا لزم واستحكم وحللته صلح الماء الحار والحمام والمرخ.

قال: وعظم العضد والساق يشتد في أربعين ليلة ثم يحل ويستعمل التليين، وإن قصف العضو أرخي الرباط.

في الزندين

قال: إن انكسر الأعلى فهو أسهل وأسلم، وإن انكسر الأسفل فشر، وإن

٢٠٩١

Figure-3. The page showing quotations from Paul of Aegina on fractures of the vertebra and the sacrum in *Kitāb al-Ḥāwī fī al-Ṭibb* [1].


De costis.
De osse pe
De spodilibus
De spatula.locus largus

Figure-4. The page showing same quotations from Paul of Aegina in *Liber Continens* [30].

On vertebra of the spine

"He said: These symptoms which occur with a contusion/fracture, if it reaches to a point of infesting the spinal cord, it will be destructive. If it occurs in the cervical vertebra, it kills quickly, because of the breath arrest. In this case namely if it pricks the spinal cord, incise on it and extract the pricked bone. But, if it does not infest, then you must mitigate the hot swelling (1,p.129;30;31,p.1339)."

"He said: Of the broken bones, the one which is remoted, segregated entirely and pricking, should always be extracted, because that bone putrefies within days, then it brings about an ulcer and it provokes the pain and the swelling (1,p.129;30;31,p.1339)."

The sacrum

"He said: If it becomes concave inwards, insert the finger into the anus, then its voice raises and it becomes straight outwards (1,p.129;30;31,p.1339)."

Another quatotation from Paul of Aegina stated that urinary and gaita incontinence may occur in anterior vertebra dislocation and if it happened at cervical level, the author warned, the patient shall die immediately. Paul of Aegina highlighted that after fracture of processus spinosum a concavity could occur in the spine and one who did not know that evolvement would mistake it for anterior vertebra dislocation.

For this part Rhazes claimed that Paul of Aegina gave a resembling statement on the treatment of kyphosis, nonetheless, he expressed that the document available is not adequate to make a decision and additional copy of this topic is needed:

On Separation of The Vertebra

"He said: If the vertebra separated inwards, the urine and the stool are retained and if the cervical vertebra is separated, the death follows quickly. However if the peduncle [processus spinosus] was broken and the spine becomes concave, this casual events do not occur, the ignorant (surgeon) suppose that it is separation of the vertebra inwards, but it is not the case (1,p.134;30;31,p.1344)."

"I say: On correction of the gibbosity, he made a statement, which is similar that was mentioned here, it is needed to inspect another copy (1,p.134-135;30;31,p.1344)."

The Second [Section] From Qaṭīṭriyūn

In this section the management of pain and weakness following blunt spine trauma is quoted from *Kitāb Buqrāt Al-Ma'rūf Bi-Qāṭīṭrīūn Ay* Ḥānūt *Al-Ṭabīb* (20) */ κατ'ἰητρεῖον* [39]**:**

"He said: One suffered the blow on his back and this disturbed him, therefore he was not strong really. We made a wool rag wet with warm olive oil and we put it on his vertebra, then we lay him down on his bad and we made him sleep on it, then we made both sides of the rag wet [again] and we fastened it (1,p.139;30;31,p.1347)."

In his comment on this topic Rhazes expressed that when vertebra dislocation or fracture is not the case there is no need for treatment except comforting the patient:

"I say: We wrote it in order to teach [you] the mode of severity of relaxation [of the patient] in this disease. There is no other treatment except relaxation, when there is no dislocation and fracture, but laceration. But when there is dislocation and fracture, after applying the bandage, foment it with wax and oil. Lest the hot swelling enlarges, several times a day the ligature should be anointed with hot oil in the winter, and fomented with cold water in the summer. I say: The constructive ligature should not be unbinded in the summer, in order to keep the condition of swelling in security; in the winter the fear will be less. These are the statements on this topic (1,p.139-140;30;31,p.1347)."

From *Kitāb Ārāʾabuqrāṭwa Aflāṭun*

In this part quoted from Galen's *De Hippocratis et Platonis placitis libri IX* [38] */περὶτῶν Ἱπποχράτους καὶΠλάτωνος δογμάτων βιβλία θ'* [39] about the findings of anterior vertebra dislocation and processus spinosus fracture, although the main notion was

not different than previous opinions. The referred authors accentuate that both conditions can be mistaken for each other leading the physician to false diagnosis. They indicated that anterior dislocation is a deadly condition whereas fracture of processus spinosum is a mild injury:

"He said: And perhaps the processus spinosi are broken and the spine is interrupted, some think that it is dislocation of vertebra of the spine inwards, but it is not; and dislocation of vertebra of the spine is destructive, but in case of fracture of the processus spinosi, there is no fear (1,p.144;30;31,p.1350)."

In his comment on this part Rhazes only added the findings after clavicle fracture and gave a short explanation:

I say: The clavicle has never been separated inwards, but there will be fear that the clavicle goes outwards when it is broken, therefore the splint is placed on this location and oppressed and always bound (1,p.144;30;31,p.1350)." With the last statement, the parts related to spine traumas in *Liber Continens* ended.

DISCUSSION

The earliest written record regarding spine injuries and accompanying paralysis is found in *Edwin-Smith Surgical papyrus* (BC 1700) [42].

The most renowned physician of antiquity, Hippocrates (BC 460-370), wrote detailed knowledge and his own observations about human spine in his different works such as *Mochlikon, On Nature of Bones, On Places in Man* and especially in *On Joints*. He classified spine injuries in 5 categories: kyphosis (relating either to a disease or trauma), scoliosis, concussion (sisis), vertebra dislocations, and processus spinosum fractures. Besides, Hippocrates described management options [26].

Much later Galen (129-200) introduced a useful knowledge on spine anatomy in his books *On Bones for Beginners (De ossibus ad tirones)* and *On the Usefulness Parts of Body (On the Usefulness of the Parts of the Body)*, and additionally in 4 comments on Hippocrates' work *On Joints* [27]. When dealing with spine disorders Galen used Hippocrates' four basic categories: Kyphosis, lordosis, scoliosis, and succession. The thoughts of Galen on spine trauma mechanisms and their managements were in concordance with those of Hippocrates [27].

Galen explained his views about medulla spinalis traumas in *On Anatomical Procedures (De anatomicis administrationibus), On the Causes of Symptoms (De symptomatum causis)*, and *On Affected Areas (De locis affectis)* [27]. Other historical important figure, which dealt with spine traumas, was Paul of Aegina (625-690). His work *Epitome* contained two sections on spine fractures and dislocations, respectively [13].

In *Liber Continens,* Rhazes quoted spine injury related parts mainly from the works of Hippocrates, Galen, Paul of Aegina and also *The Book Attributed to Galen*, which is believed to be written by Galen. Rhazes took the knowledge from the mentioned authors in verbatim and then he wrote his own comments on the related topic. In some sections these comments seem irrelevant and his contribution is somehow negligible. Still, the transmission of once forgotten valuable information's by Rhazes had deeply affected western medicine.

Paul of Aegina's work had been accepted one of the fundamental sources for spine injuries during the middle ages. Regarding this issue, Haly Abbas (930-996) [7] and Avicenna (980-1037) [2], the other two prominent physicians of Islamic Golden Age, too benefited principally from Paul of Aegina's work. Paul of Aegina's statement about the poor prognosis in the case of medulla spinalis involvement and likewise deadly outcome when it occurs in cervical level was reiterated in Rhazes work with great emphasis. Paul of Aegina, unlike Hippocrates and Galen, recommended removal of bones when they penetrate medulla spinalis [13,16,21], which account was also recognized by Rhazes and retold in the book. Paul of Aegina's work *Epitome* contained a detailed and extensive section regarding spine dislocations [32].

For some unknown reason, Rhazes included only a brief quotation from that work in *Liber Continens* and he commented that the reader should review another copy of *Epitome*. It is probable that Rhazes did not possess the full copy of *Epitome* during creating his work, although he knew much about its contents. Or, he found the knowledge too detailed or complicated for physicians and suggested further reading when they were interested in. On the other hand, Rhazes quoted the knowledge regarding the managment of thoracal and cervical vertebra dislocations from Galen's *Kitāb Ārāʾ Abuqrāṭ wa Aflāṭun*, which topic was not included in Paul of Aegina's *Epitome*. Haly Abbas too did not address the treatment of posterior vertebra dislocation in his *Liber Regalis* [7] whereas Avicenna included the mentioned issue in his *Canon of Medicine* [2]. This may indicate that when writing the *Canon* Avicenna may have primarily benefited both from Galen and Rhazes. Same management methods were also included in Ismāʿīl Jorjani's (1042-1137) *Ẕākhīra Kh'arazmshāhī* [3], which show that some of the medieval Islamic physicians followed in the footsteps of certain antique pioneers.

In *Liber Continens* when quoting previous writers Rhazes presented either the name of the work or the name of author for the spine injury section. For example, when Rhazes cited Paul of Aegina he did not give the name of *Kunnāsh*. On the other hand, when he quoted *Manafiʿ al-Aʿḍāʾ* and *Kitāb Ārāʾ Abuqrāṭ wa Aflāṭun* he did not mention Galen or while he gave the name of *Qāṭīṭriyyūn* and *Abīẕīmiyyā* he did not name Hippocrates. It seems that this arrangement was designed in an unplanned manner.

CONCLUSION

Rhazes's *Liber Continens* was an influential medical work during medieval times both in the Islamic geography and in the Western World. When creating *Liber Continens* he mostly benefited from various schools including Greek, Syriac, Arabic, Persian, and Hindu. However, he followed purely Greco-Roman tradition in writing the sections related to spine injury. Rhazes focused essentially on the opinions of Hippocrates, Galen, and Paul of Aegina for classification, underlying mechanisms, and management options of spine traumas, nonetheless, his contributions on this topic were insignificant. Starting with *Liber Continens* Greco-Roman school's views had become more powerful in the Islamic World.

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REFERENCES

1- Abū Bakr Muḥammed b. Zakariyyā al-Rāzī. *Al-Ḥāwī fī al-Ṭibb.* First Edition**.** Maracaʿa wa taṣḥīḥ: D. Muḥammad Muḥammad Ismāʿīl. Vol. 5, Cuzʾ. 13, Dar Al-Kotob Al-ilmiyah, Beirut 1421 h - 2000 m; pp: 1-113 [1965-2232] (Arabic).

2- Aciduman A, Belen D, Simsek S. Management of spinal disorders and trauma in Avicenna's Canon of Medicine. *Neurosurgery* 2006; 59 (2): 397-403.

3- Acıduman A, Şems Ş. Cürcânî'nin ünlü eseri *Zahîre-i Harezmşâhî*'de omurga anatomisi ve omurga travmaları üzerine [On the spine anatomy and the spine traumas in Jorjânî's famous work *Zahîre-i Harezmşâhî*]. In: Demirci M, Temizel A, Hacıgökmen MA, Solmaz S (Eds). *II. Uluslararası Selçuklu Kültür ve Medeniyeti Sempozyumu, Selçuklularda Bilim ve Düşünce [The Second International Seljukid Culture and Civilisation Symposium Science and Thought* 400 *in Seljukid Era], Bildiriler / Proceedings, 19-22 Ekim [October] 2011, Konya-Turkey*. Vol 3, Selçuklu Belediyesi Yayınları, Konya 2013; pp: 249-276 (Turkish).

4- Ağırakça A. *History of Islamic Medicine [From the Beginning to the VII/XIII Century].* Akdem Yayınları, İstanbul 2010; pp: 162, 176-177.

5- [Akalın] BÖ. *Nevsāl-i ʿĀfiyet, Sālnāme-i Ṭibbī.* Fourth Book, Maṭbaʿa-i Aḥmed İhsān, İstanbul 1322; pp: 171-184 (Turkish).

6- Al-Bayrūnī: Risālat al-Bayrūnī fī Fihrist Kutub Muḥammad b. Zakariyyā al-Rāzī. Iʿtinā bi-Nashrihā wa Taṣḥīḥhā: Kraus B. Paris: Maṭbaʿa al-Ḳalam, 1936. In: *Islamic Medicine Volume 24 Muḥammad ibn Zakarīyāʾ Al-Rāzī (d. 313/925) Text and Studies I.* Collected and reprinted by Sezgin F in collaboration with Amawi M, Ehrig-Eggert C, Neubauer E. Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, Frankfurt am Main 1996; pp: 266-320 (Arabic).

7- Belen D, Aciduman A. A Pioneer from the Islamic Golden Age: Haly Abbas and spinal traumas in his principal work, *The Royal Book*. *J Neurosurg Spine* 2006; 5 (4): 381-383.

8- Browne EG. *Arabian Medicine: Being the Fitzpatrick Lectures Delivered at the College of Physicians in November 1919 and November 1920.* Cambridge University Press, London 1921; pp: 43, 46-47. (https://ia802706.us.archive.org /2/items/ 39002086349124. med. yale. edu/ 39002086349124.med.yale.edu.pdf) [Accessed: January 07, 2017].

9- Bryson JS. *The Kitāb al-Ḥāwī of Rāzī (ca. 900 AD), Book One of the Ḥāwī on Brain, Nerve, and Mental Disorders: studies in the transmission of medical texts from Greek into Arabic into Latin.* A Dissertation Presented to the Faculty of Graduate School of Yale University in Candidacy for the Degree of Doctor of Philosophy. Dissertation Director: Gutas D, December 2000. UMI Dissertation Service, Bell & Howell Information and Learning Company, Ann Arbor 2001.

10- Campbell D. *Arabian Medicine and Its Influence on the Middle Ages.* Reprinted from the edition of 1926. AMS Press Inc., London. New York, N.Y., 1973; pp: 65-72.

11- Castiglioni A. *A History of Medicine.* Second Edition. Translated from the Italian and edited by Krumbhaar EB. Alfred A. Knopf, New York 1958; pp: 267-270.

12- Elias AE. *Elias' Modern Dictionary Arabic-English.* Seventh Edition. Elias' Modern Press, Cairo 1954; pp: 332, 583.

13- Er U, Naderi S. Paulus Aeginata: review of spine-related chapters in "Epitomoe Medicoe Libri Septem". *Spine* 2013; 38 (8): 692-695.

14- Galen. *On the Usefulness of The Parts of The Body, περὶ χρείας μορίων, De usu partium.* Translated from Greek with an introduction and commentary by Tallmadge May M. Vol 2, Cornell University Press, Ithaca, N.Y. 1968; pp: 554, 557-558.

15- Goodman LE. Al-Rāzī. In: Bosworth CE, Van Donzel E, Heinrichs WP, Lecomte G assisted by Bearman PJ and Nurit MS (Eds). *The Encyclopaedia of Islam.* New Edition. E.J. Brill,Leiden 1995; pp: 474-477.

16- Goodrich JT. History of spine surgery in the ancient and medieval worlds. *Neurosurg Focus* 2004; 16 (1): E2.

17- Hunke S. *Allahs Sonne über dem Abendland Unser arabisches Erbe.* Fischer Taschenbuch Verlag, Frankfurt am Main 1965 (German) (https://archive.org /details/HunkeSigridAllahsSonneUberDemAbendlandUnserArabischesErbeFischerFrankfurtAmMain1965) [Accessed January 06, 2017].

18- İzmirli İsmail Hakkı. Shaykh al-Aṭibbā Abū Bakr Muḥammad bin Zakariyyā al-Rāzī. *Dār al-Funūn İlâhiyyāt Fakültesi Mecmūʿası* 1925; 1 (1): 151-165.

19- Kaya M. Ünlü hekim-filozof Ebû Bekr er-Râzî ve hekimlik ahlâkı ile ilgili bir risâlesi [Famous physician and philosopher Abû Bakr ar-Râzî and his pamphlet on morality of medical ethics]. *Felsefe Arkivi* 1987; 26: 227-246.

20- Kitāb Buqrāt Al-Maʿrūf Bi-Qāṭīṭrīūn Ay Ḥānūt Al-Ṭabīb (Hippocrates in the Surgery). Edited and translated with Introduction, Notes and Glossary by Lyons M.C. In: *Arabic Technical and Scientific Texts.* Vol 3, W. Heffer &Sons Ltd, Cambridge 1968; p: 16.

21- Knoeller SM, Seifried C. Historical perspective: history of spinal surgery. *Spine* 2000; 25 (21): 2838-2843.

22- Lane EW. *An Arabic-English Lexicon,* in Eight Parts**.** Part 7, Librairie du Liban, Beirut 1968; p: 2492.

23- Leclerc L. *Histoire de la Médecine Arabe.* Tome Premier, Ernest Leroux, Paris 1870; p: 338 (https://books.google.com.tr /books?id=9UYCATvdSy EC &printsec=frontcover&dq=Leclerc,+Arabe&hl=tr&sa=X&redir_esc=y#v=onepage&q=Leclerc%2C%20Arabe&f=false) [Accessed July 23, 2016].

24- Leonardo RA. *History of Surgery.* Froben Press, New York 1943; p: 87.

25- Lessico. Razi Rhazes Rasis Rahzes Abu Bakr Muhammad ibn Zakaryya al-Razi (http://www.summagallicana.it/lessico/r/Razi%20Rhazes%20Rasis%20Rahzes.htm) [Accessed January 10, 2017].

26- Marketos SG, Skiadas P. Hippocrates: the father of spine surgery. *Spine* 1999; 24 (13):1381-1387.

27- Marketos SG, Skiadas PK. Galen: a pioneer of spine research. *Spine* 1999; 24 (22): 2358- 2362.

28- Meyerhof M. Science and medicine. In: Arnold T, Guillaume A (Eds). *The Legacy of Islam.* Clarendon Press, Oxford 1931; pp: 311-354.

29- Meyerhof M. Thirty-three clinical observations by Rhazes (Circa 900 A.D.). *Isis* 1935; 23 (2): 321-372.

30- Mohammed Rhasis. *Liber Elhavi, seu Ars medicinae (Latine).* Jacobus Britannicus, 1486. (http://books.google.com.tr /books?id=gphmJFXT rawC&printsec=frontcover&dq=liber+elhavi&hl=tr&sa=X&ei=t1x2UefCYXjtQa1q IHIBA&redir_esc=y) [Accessed June 24, 2012].

31- Muḥammad Zakariyyā Razī. *Al-Ḥāwī fī al-Ṭibb.* Kod-Gozārī ve Umūr Elektronīkī: Doktor Ḥusayn Hātamī. Part 13, pp: 1247-1360 (http://www.general-files.com/go/140364656000)[Accessed July 17, 2012] (Arabic).

32- Paulus Aeginata. *The Seven Books of Paulus Aeginata.* Translated from the Greek With A Commentary Embracing A Complete View of the Knowledge Possessed by the Greeks, Romans, and Arabians On All Subjects Connected With Medicine and Surgery by Adams F, in Three Volumes. Vol II, Printed for the Sydenham Society, London 1846; p: 392(https://books.google.com.tr /books?id= GIBhAAAAIAAJ&printsec=frontcover&dq=Paulus+Aegineta.+The+Seven+-Books+of+Paulus+Aegineta&hl=tr&sa=X&ved=0ahUKEwic65WfkuQAhXkDMAKHYg9AnUQ6AEIXDAI#v=onepage&q&f=false) [Accessed March 12, 2010].

33- Radbill SX. The first treatise on pediatrics. *Amer J Dis Child* 1971; 122 (5): 369-376.

34- Ranking GSA. The life and works of Rhazes (Abū Bakr Muḥammad bin Zakarīya ar-Rāzī). In: *Muḥammad Ibn Zakarīyāʾ Al-Rāzī (d. 313/925), Text and Studies II.* Collected and reprinted by Sezgin F in collaboration with Amawi M, Ehrig-Eggert C, Neubauer E. Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, Frankfurt am Main 1996; pp: 73-104.

35- Robinson V. *The Story of Medicine.* Reprinted. The New Home Library, New York 1944; pp: 154, 157-158.

36- Sadi LM. The millenium of ar-Razi (Rhazes) (850-932 A.D.?). In: *Islamic Medicine Volume 25 Muḥammad ibn Zakarīyāʾ Al-Rāzī (d. 313/925) Text and Studies II.* Collected and reprinted by Sezgin F in collaboration with Amawi M, Ehrig-Eggert C, Neubauer E. Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, Frankfurt am Main 1996; pp: 252-262.

37- Samy-Bey Fraschery. *Dictionnaire Universel D'Histoire et De Géographie.* Tome Premier, Editeur Mihran, Constantinople 1889; pp: 693-696 (Turkish).

38- Sarton G. *Introduction to the History of Science.* Reprinted. Vol 1, The Williams & Wilkins Company, Baltimore 1953; pp: 98, 305, 609-610.

39- Sezgin F. *Geschichte Des Arabischen Schrifttums.* Medizin-Pharmazie, Zoologie, Tierheilkünde Bis ca. 430 H. Band 3, E.J. Brill, Leiden 1970; p: 34, 36, 45, 105, 106, 169.

40- The Wellcome Trust Limited [GB]. S0001954. Credit: Wellcome Library, London. *Portrait of Rhazes (al-Razi) (AD 865-925) physician and alchemist who lived in Baghdad.* Coloured print. Collection: Wellcome Images. (https://wellcomeimages. org/indexplus/ result.html? *sform=welcomeimages &_IXACTION_=query&%24%3Dtoday=&_IXFIRST_=1&%3Did_ref=S0001954&_IXSPFX_=templates/t&_IXFPFX_=templates/t&_IXMAXHITS_=1&s=2d9HY3EVETL)[Accessed January 08, 2017].

41- Ulmann M. *Islamic Medicine.* Edinburgh University Press, Edinburgh 1978; pp: 43-44.

42- Wilkins RH. Neurosurgical Classic-XVII. *J Neurosurg* 1964; 21 (3): 240-244.